MODIS Science Team Member

Semi-Annual Report

(Jan - Jul 2002)

Eric Vermote (University of Maryland) – Science Team Member

John O' Bannon (UMD), Lisa Ojanen (UMD), James Ray (SSAI), Nazmi El Saleous (RSTX),

Contract: NAS5-96062

A. FOCUS ACTIVITIES DURING THE REPORTING PERIOD

The most important activities undertaken during this reporting period are the following:

1. Land surface reflectance code development, testing and delivery
2. Internal products refinements (cloud, cloud shadow, fire)
3. Aqua data
4. 3.75mic reflectance and associated products
5. Development of continental data set from MOD09A1 (8 days composite surface reflectance)
6. Evidence of directional hot spot in surface reflectance data
7. MODIS Adaptive Processing System (MODAPS)/PI Processing

1. Land surface reflectance code development, testing and delivery

Several corrections were done to the code for generating Level 2, Level 3 land surface reflectance and thermal anomaly products (MOD_PR09, or PGE 11).

1.1 Level 2 surface reflectance

- Improve code robustness in checking NCEP ancillary input
- Improve the aerosol interpolation routine
- Add information to the coarse resolution file (ozone, air temperature,…) to facilitate QA and validation
- Add Climate modeling grid output (0.05deg x 0.05deg geographic projection)
- Add information about the processing environment to the metadata (Linux or SGI)
- Improve internal cloud mask
- Develop internal shadow mask (based on geometric approach) (See details in Shadow mask section)
- Prepare public release version of PGE11 by deleting non releasable features (part of the Miami code)
- Test Linux version and analyze differences between Linux and SGI versions
- Improve the internal fire mask (false alarms see details in the internal fire mask section)
- Make changes to the Aqua version after analysis of the first data so aerosol retrieval does not use band 6 data

1.2 Level 3 surface reflectance

- Improve performance and robustness of the code
- Work on the collection 4 algorithm, which make use of internal cloud mask and cloud shadow mask and still the rest of the QA flags (aerosols) therefore considerably simplifying the composite process.

2. Internal products refinements

2.1 Internal cloud mask

The internal cloud mask has been extensively evaluated prior to and during the science tests of the collection 4 data. Statistical approach has been used by the Land Data Operational Product Evaluation (QA group) to point out and analyze differences between the MODIS cloud mask (MOD35) and the internal MOD09 cloud mask (http://landdb1.nascom.nasa.gov/MOD09_CLD/). This evaluation has enabled refinement and improvements in both cloud mask approaches, which are now comparable. Most of the downstream products are now using both cloud masks in their data selection and weighting approaches. An example of the analysis of the internal QA is provided below (figure 1), it represents one of the cases posted on the land QA home page comparing the two cloud masks. This particular case illustrates an error of commission of MOD35, an area appearing clear in the surface reflectance product and not labeled as cloud by the MOD09 internal cloud mask is flagged as cloudy or partially cloudy in MOD35).

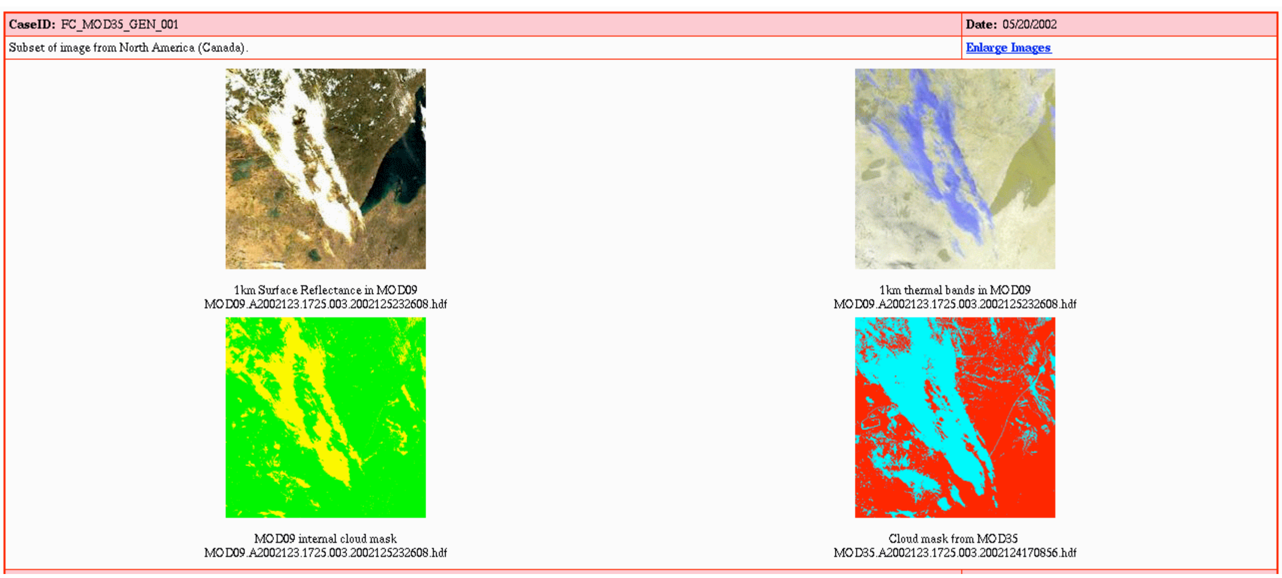

Figure 1: One of the cases posted on the MODLAND QA page, after statistical comparison of MOD35 and MOD09 internal cloud mask.

2.2 Internal cloud shadow mask

An internal cloud shadow mask has been developed based on the internal cloud mask, a rough estimate of cloud altitude using the thermal infrared channels and a geometric approach. The evaluation of the cloud and cloud shadow mask can be done by selecting two scenes taken a few days apart over the same location, one free of clouds which will be used as a reference and the other cloudy. Desert areas are good candidates since BDRF effects are smaller than in vegetated areas and the surface conditions are very stable. Figure 2 shows a RGB true color of an area located in Sahara desert. Using the difference in MODIS band 3 between the two dates, and by simple thresholding we are able to mask most the clouds in the cloudy scene (Figure 3). The same approach is used to create a cloud shadow mask, this time band 5 is used since it is more reflective than band 3 and less sensitive to atmospheric effect, and the values under a certain threshold are labelled cloud shadow, the results are illustrated in figure 4. Using those independently derived cloud and cloud shadow masks, we can evaluate the internal cloud mask (figure 5), and the internal cloud shadow mask (figure 6). On this particular case, it can be seen that the internal cloud and cloud shadow perform very well, both seem to flag a little more pixel as either cloud or shadow. One must keep in mind that thin cloud and brighter shadow are more difficult to detect by the difference approach and that it is generally better to filter out more pixels which are not useful for further analysis (such as cloud or cloud shadow), than to let “bad” pixels through.

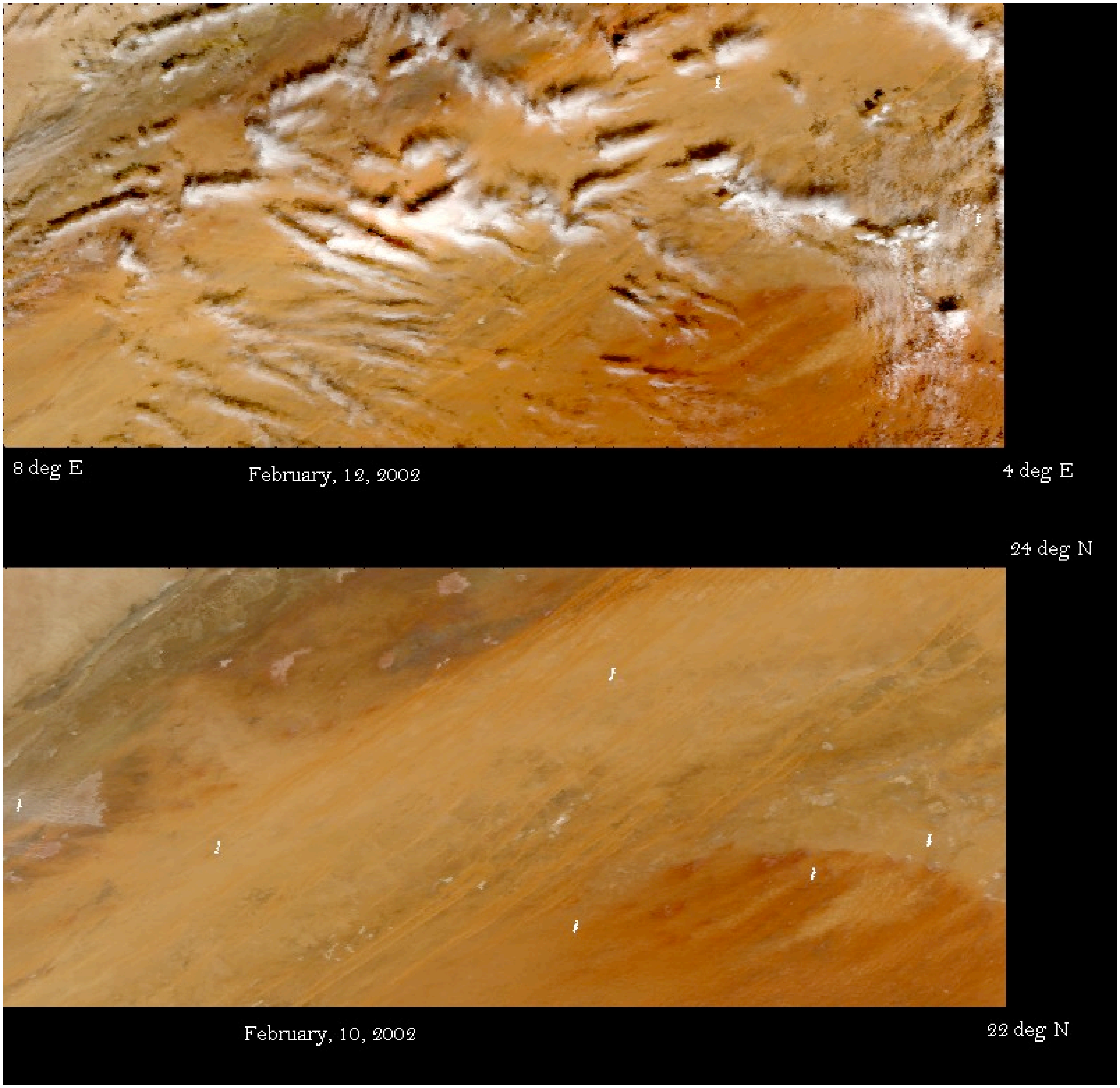

Figure 2: Area in the Sahara desert south of Algeria selected to test the cloud and cloud shadow mask. The cloud free reference image (below) was acquired on February, 10, 2002 just a few days before the cloudy image (February, 12, 2002) which clearly shows the cloud and most importantly the cloud shadow on this reflective surface.

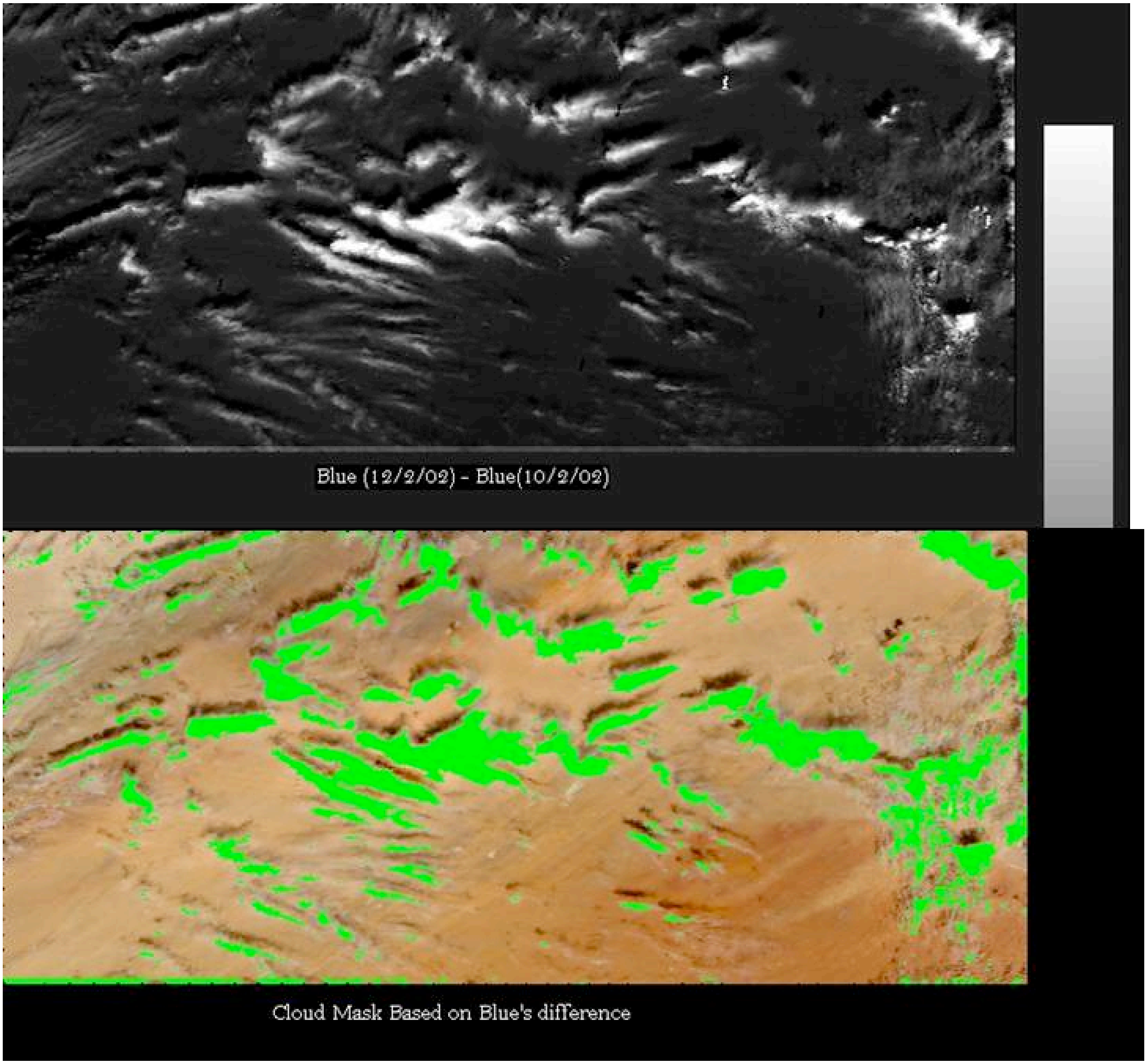

Figure 3: Illustration of the evaluation of the internal cloud mask. Using the difference between the clear and the cloudy scene in the MODIS 500m blue channel (band 3) (top of figure 3), a cloud mask (see the green in bottom of figure 3) is generated by labeling every values above a given threshold as cloud.

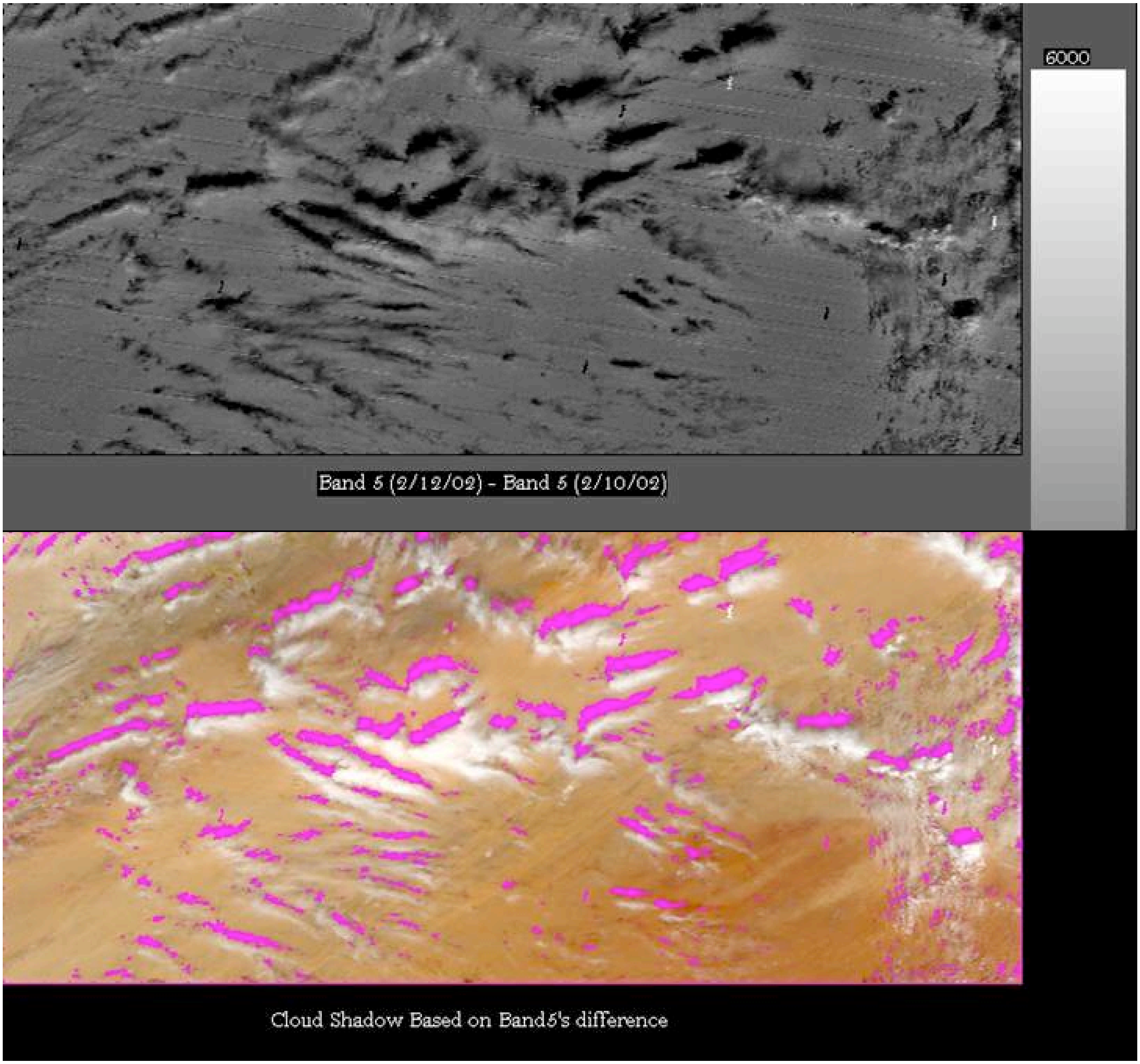

Figure 4 Illustration of the evaluation of the internal cloud shadow mask. Using the difference between the clear and the cloudy scene in the MODIS 500m near infrared channel (band 5) (top of figure 4), a cloud shadow mask (see the Magenta in bottom of figure 4) is generated by labeling every values below a given threshold as cloud.

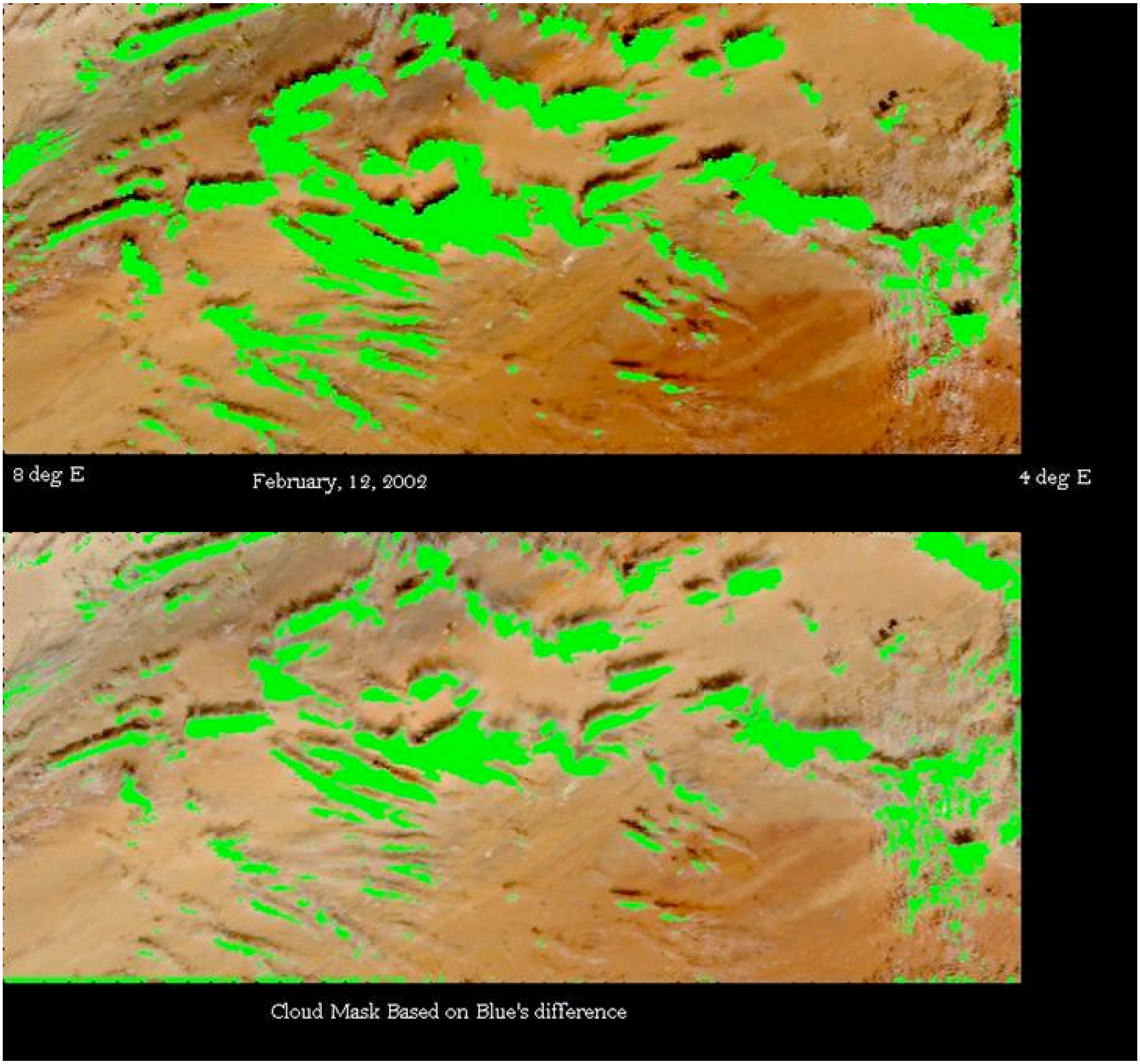

Figure 5: Evaluation of the internal cloud mask on February 12, 2002 (top image), by comparison to the cloud mask obtained by difference with a cloud free day (bottom).

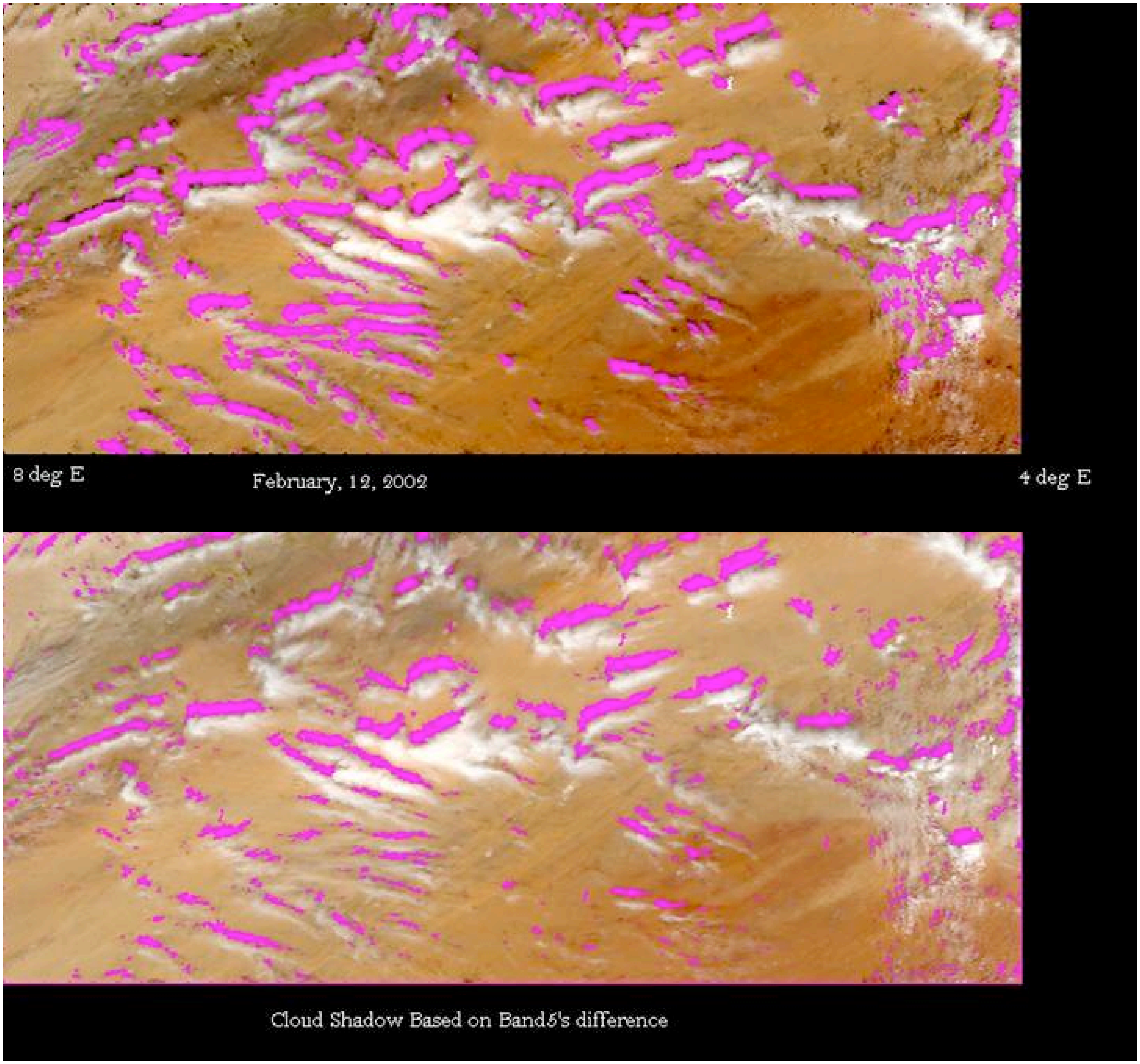

Figure 6: Evaluation of the internal cloud shadow mask on February 12, 2002 (top image), by comparison to the cloud shadow obtained by difference with a cloud free day (bottom).

2.3 Internal fire mask

The internal fire mask has been refined by comparison to the standard MODIS product (MOD14). The approach for both detection methods is based on the use of the 1km middle infrared channels (channel 20 at 3.75mic and 21 at 3.95mic), which are sensitive to hot sub pixel features. The standard approach uses a contextual algorithm which was previously applied extensively to NOAA-AVHRR and TRIM-VIIRS data set, the internal fire mask relies on a spectral scheme that uses the reflective component in the middle infrared to detect fire and is a pixel based approach. Comparison to the standard product detected false alarms in the internal fire mask which have been occurring primarily on very bright targets such as desert surfaces and also for off nadir view where atmospheric correction is more problematic. The internal fire mask algorithm has been modified to account for uncertainties in surface effect and the geometry by introducing some error term depending on view angle and predicted surface reflectance. Figures 7a-d illustrate the result of the improvements described above. Figure 7a shows a RGB picture of the study area, figure 7b shows the results of the contextual algorithm MOD14, figure 7c shows the results of the internal fire mask version 0 also outlining area of false alarm (white ellipses) over off nadir bright area (top of the image) and off nadir again on the edges of clouds (bottom right). Changes introduced in version 1, eliminate those problems as shown in figure 7d. Those changes however do not substantially degrade the performance of the algorithm as shown in figure 8a-e, where the details over the red ellipse area are enlarged. Even for those off nadir observations, most of the fires are still detected by version 1 internal fire algorithms. The number of fire detected in that particular case is still substantially higher than the one detected by the version of the contextual algorithm available at that time (see figure 8e).

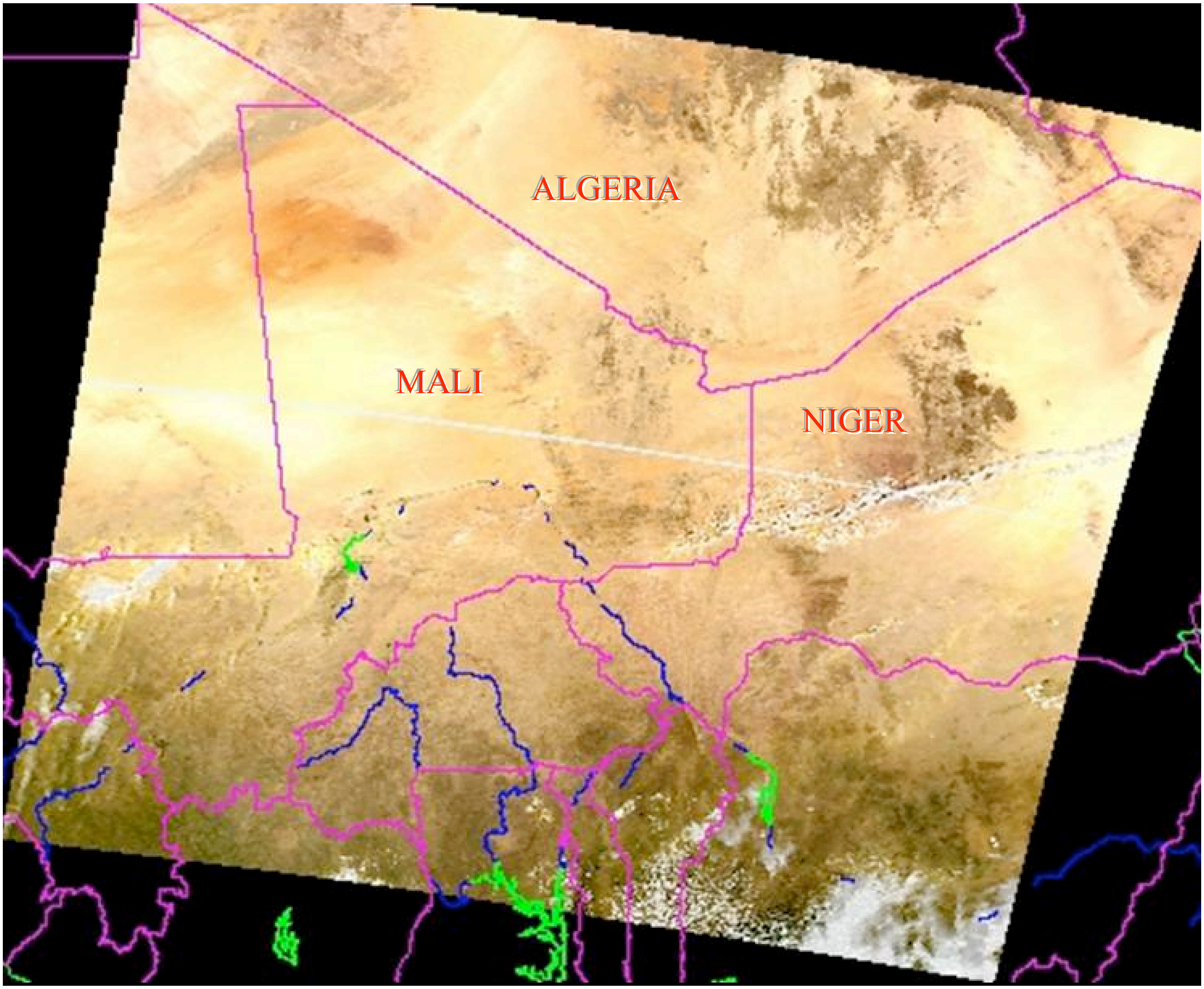

Figure 7a: RGB image of a MODIS granule over Sahel where false alarms were detected in the internal fire mask product. Country boundaries are in Magenta, river in blue, and lake shoreline in green.

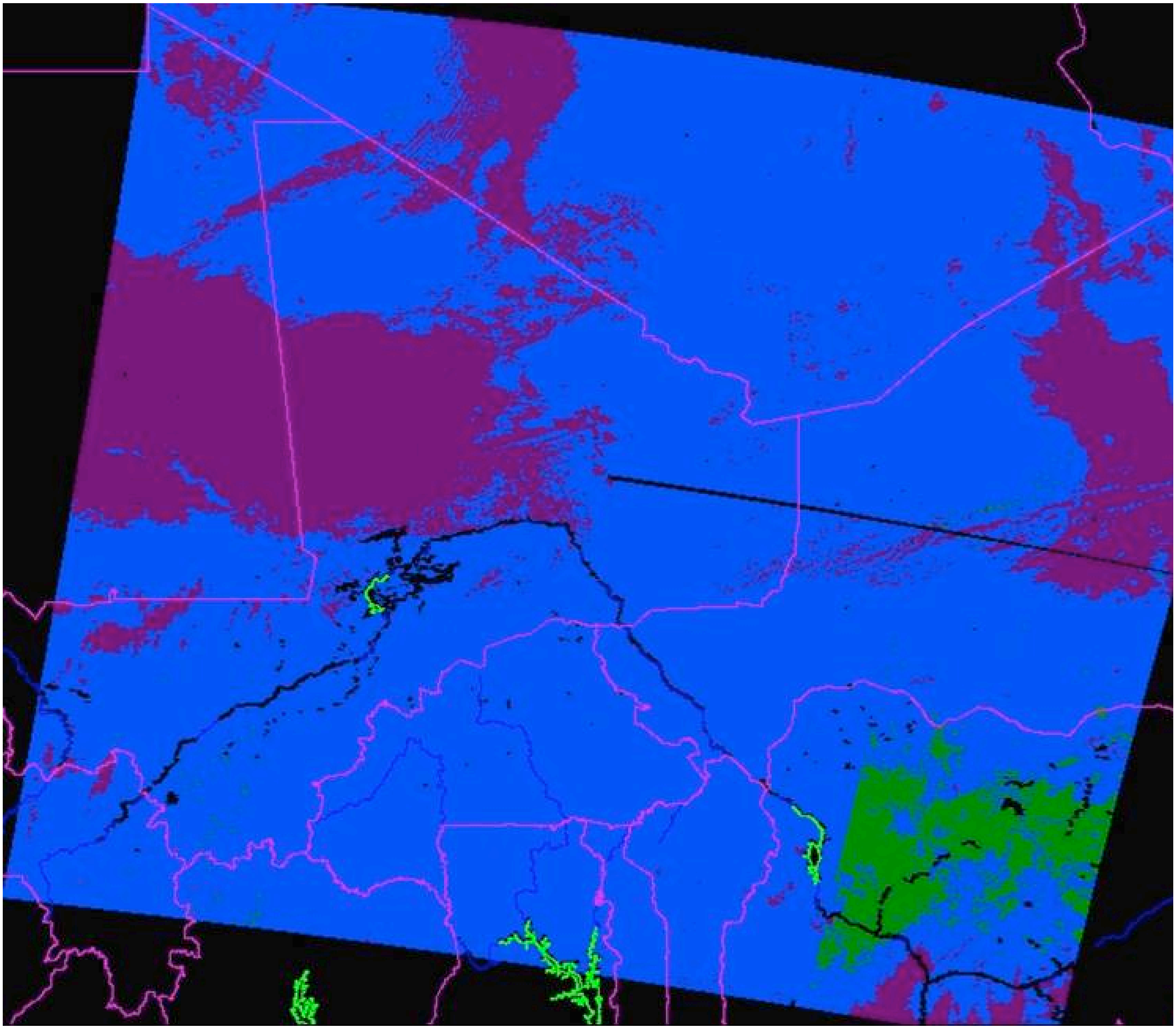

Figure 7b: MOD14 fire mask results, very limited fire activity is occurring in the bottom left part of the granule.

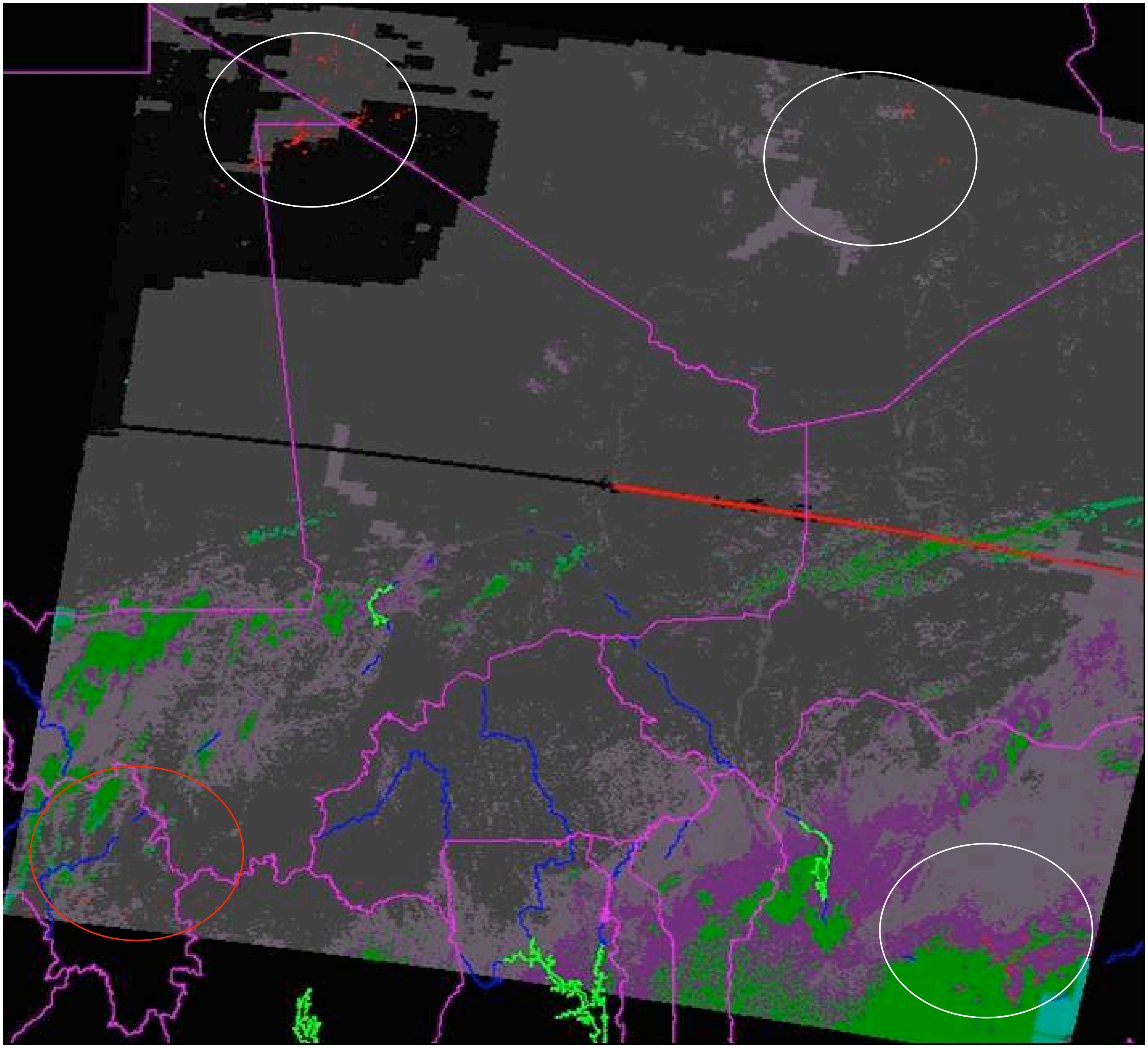

Figure 7c: Internal fire mask version 0 results (fire are red dots), white ellipses outline areas of false alarm, the red ellipse outlines an area where actual fires are occurring.

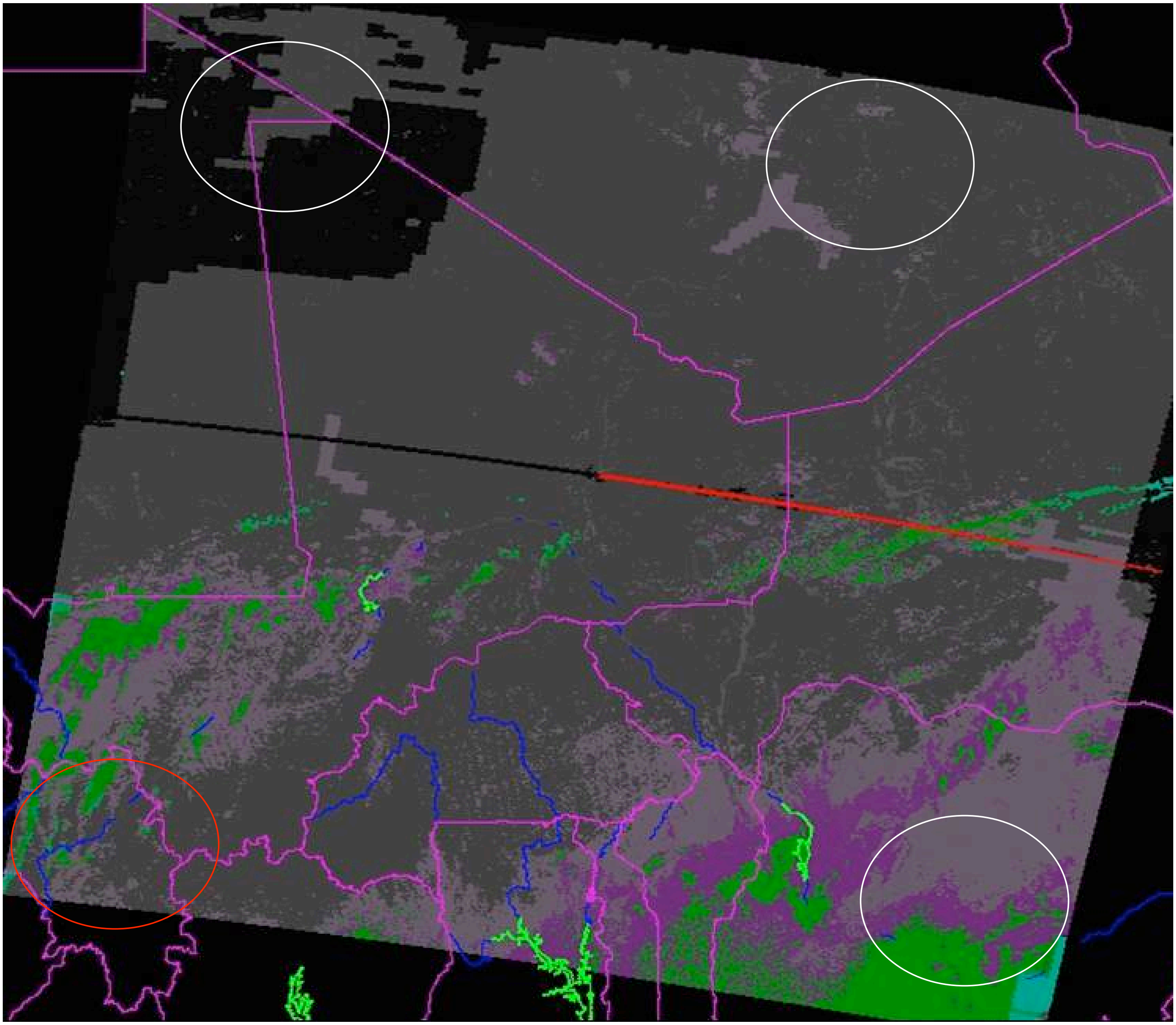

Figure 7d: Internal fire mask version 1 results (fires are red dots), we have introduced a corrective uncertainty term depending on surface brightness (reflectance predicted using band 6 and 7) and view angle (transmission effect), the false alarms in the white ellipses were eliminated.

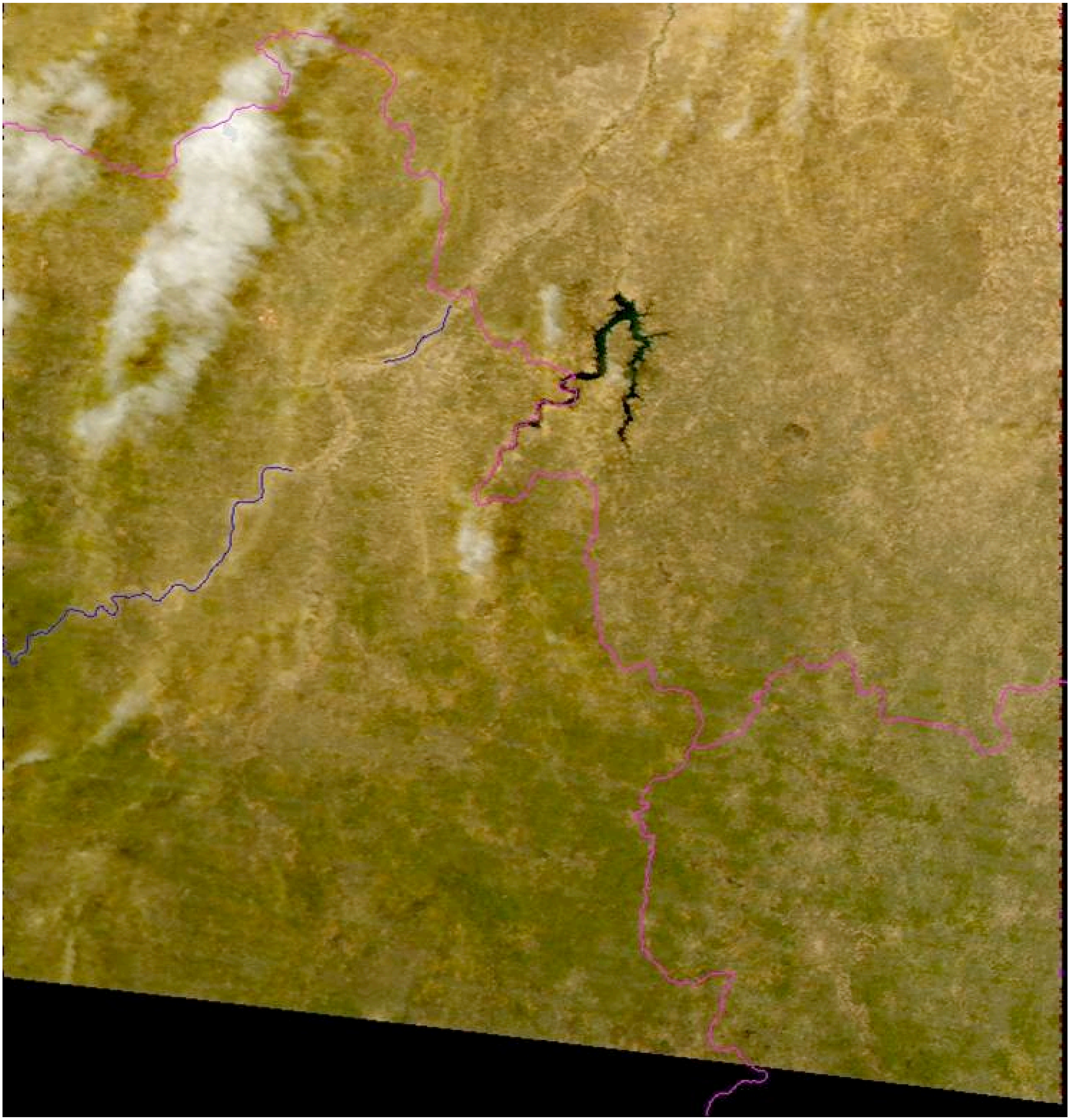

Figure 8a: Enlarged details over the red ellipse area, RGB image of the surface reflectance.

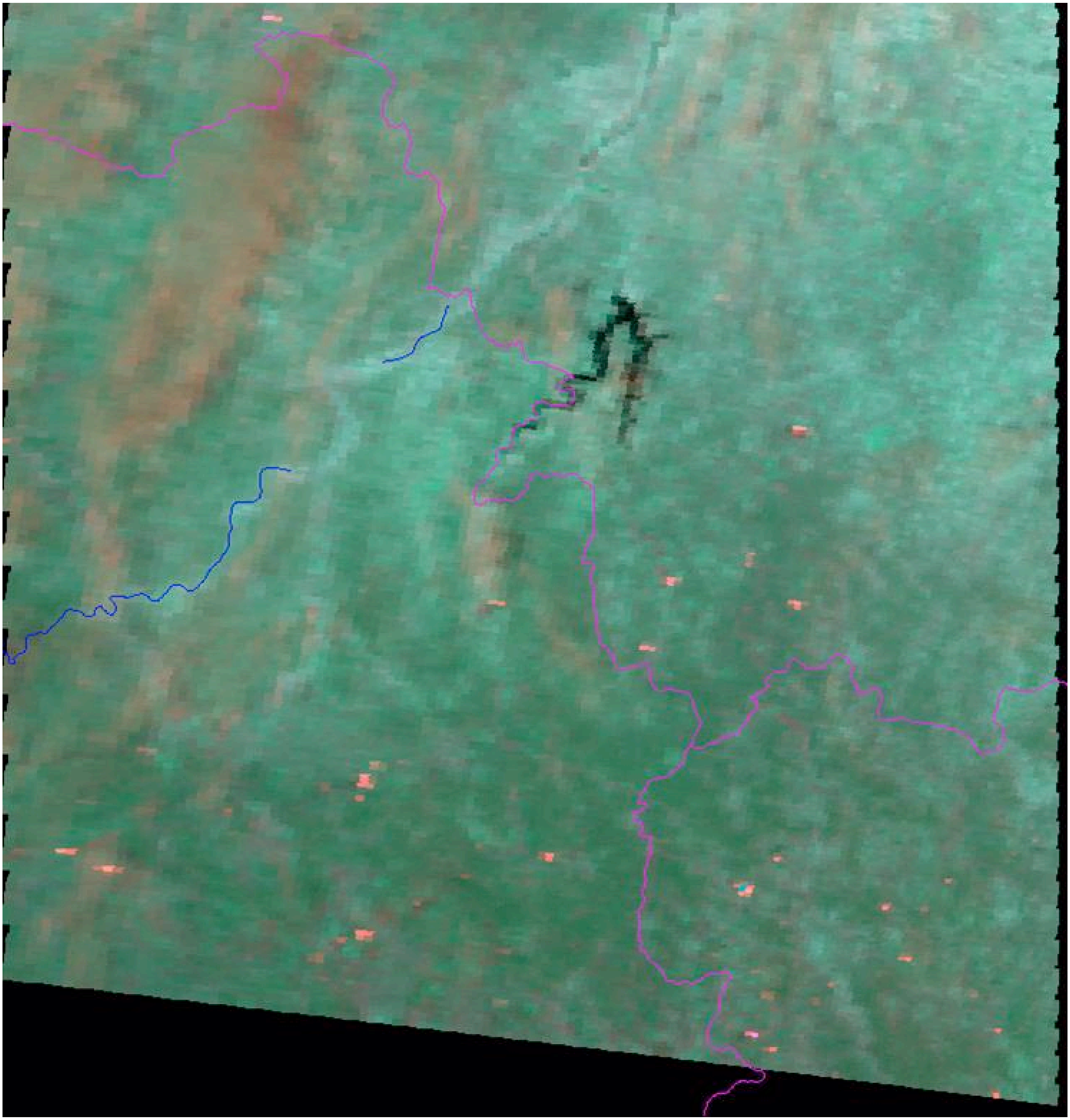

Figure 8b: Enlarged details over the red ellipse area, thermal anomaly RGB (R=middle infrared reflectance, G=1.61mic, B=2.13mic), the fire appears naturally as bright red spots.

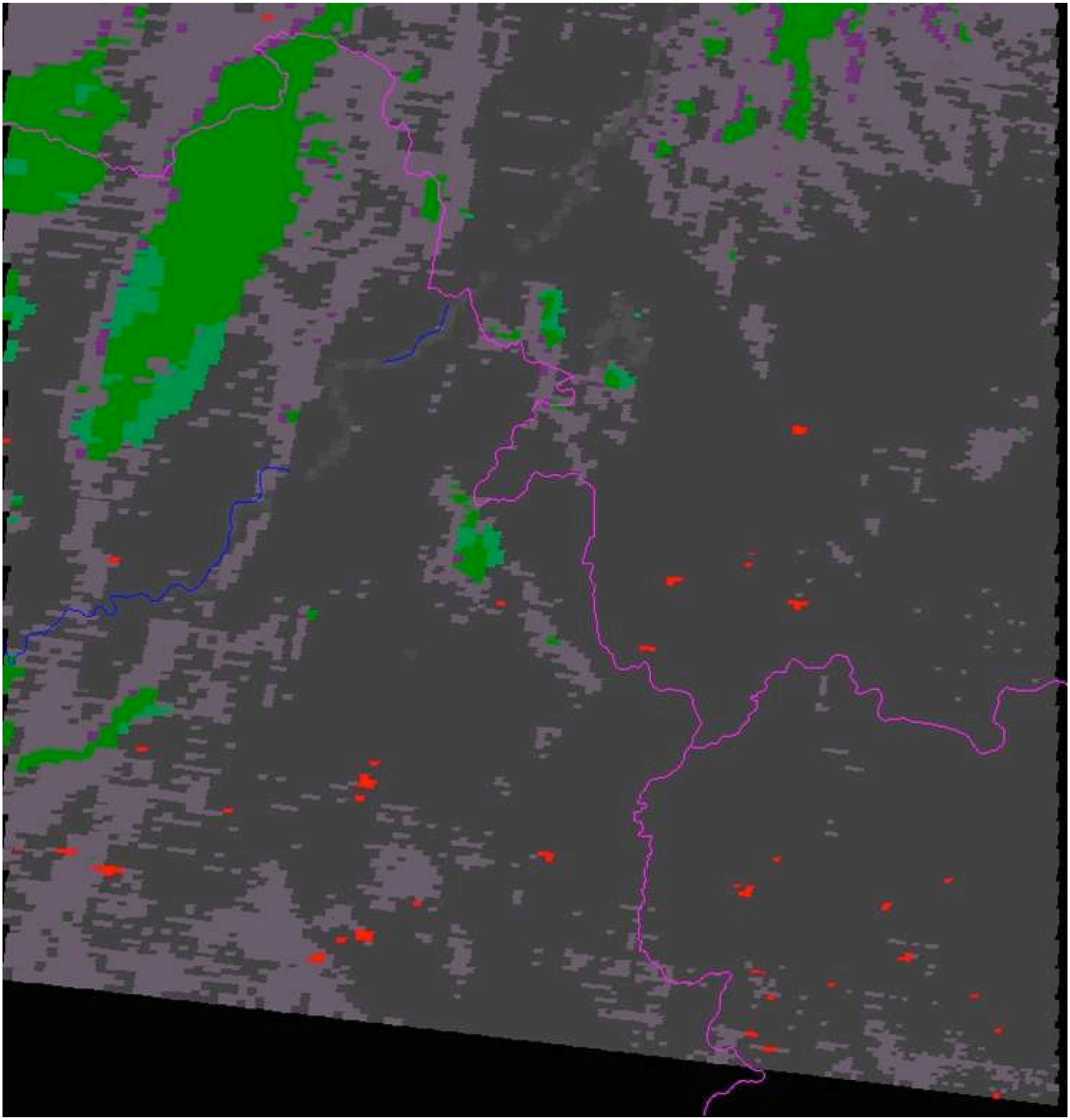

Figure 8c: Enlarged details over the red ellipse area, version 0 internal fire mask, all the fires even the ones with less energy are detected by the algorithm.

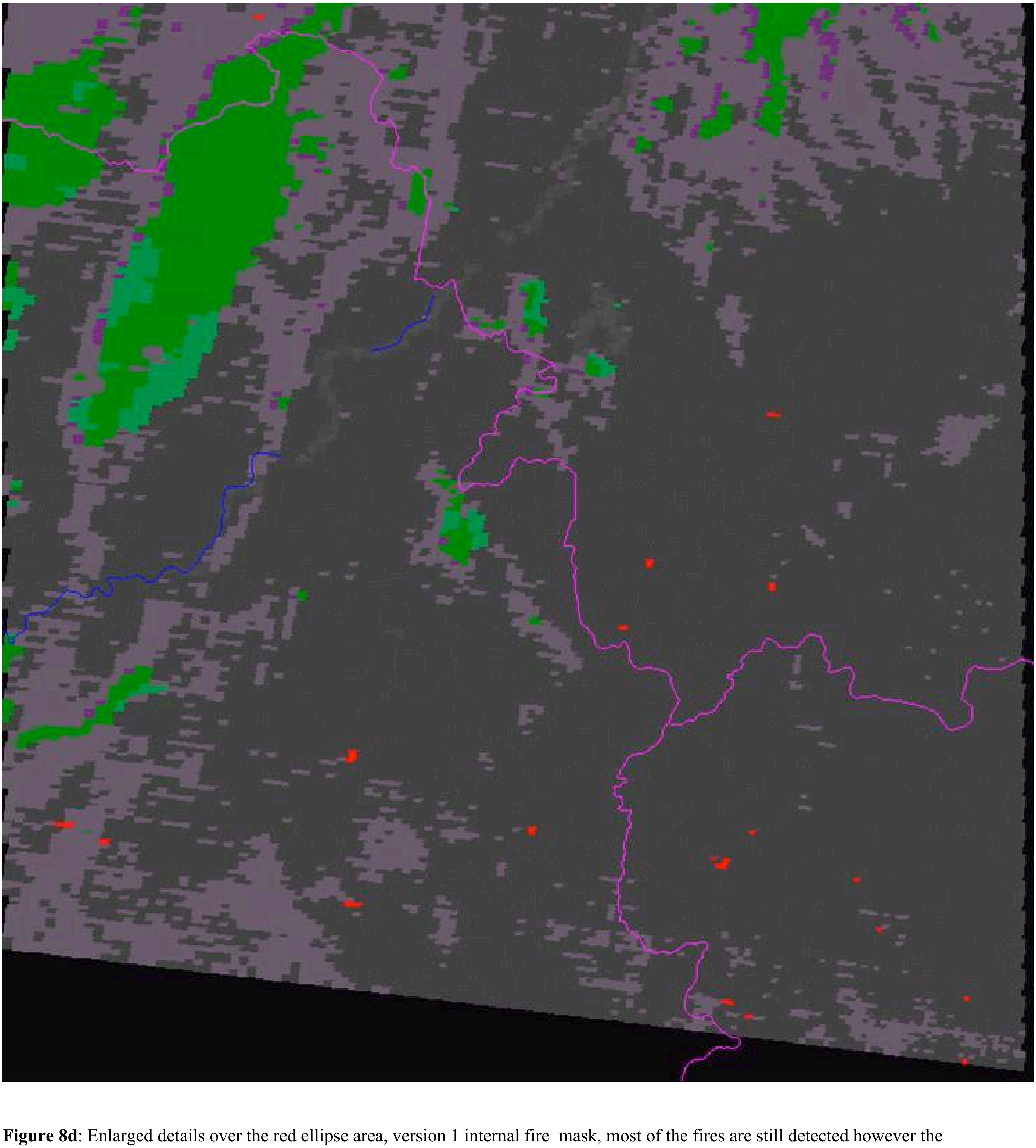

Figure 8d: Enlarged details over the red ellipse area, version 1 internal fire mask, most of the fires are still detected however the smallest ones are not, due to the introduction of the error terms and the fact this portion of the image is off nadir.

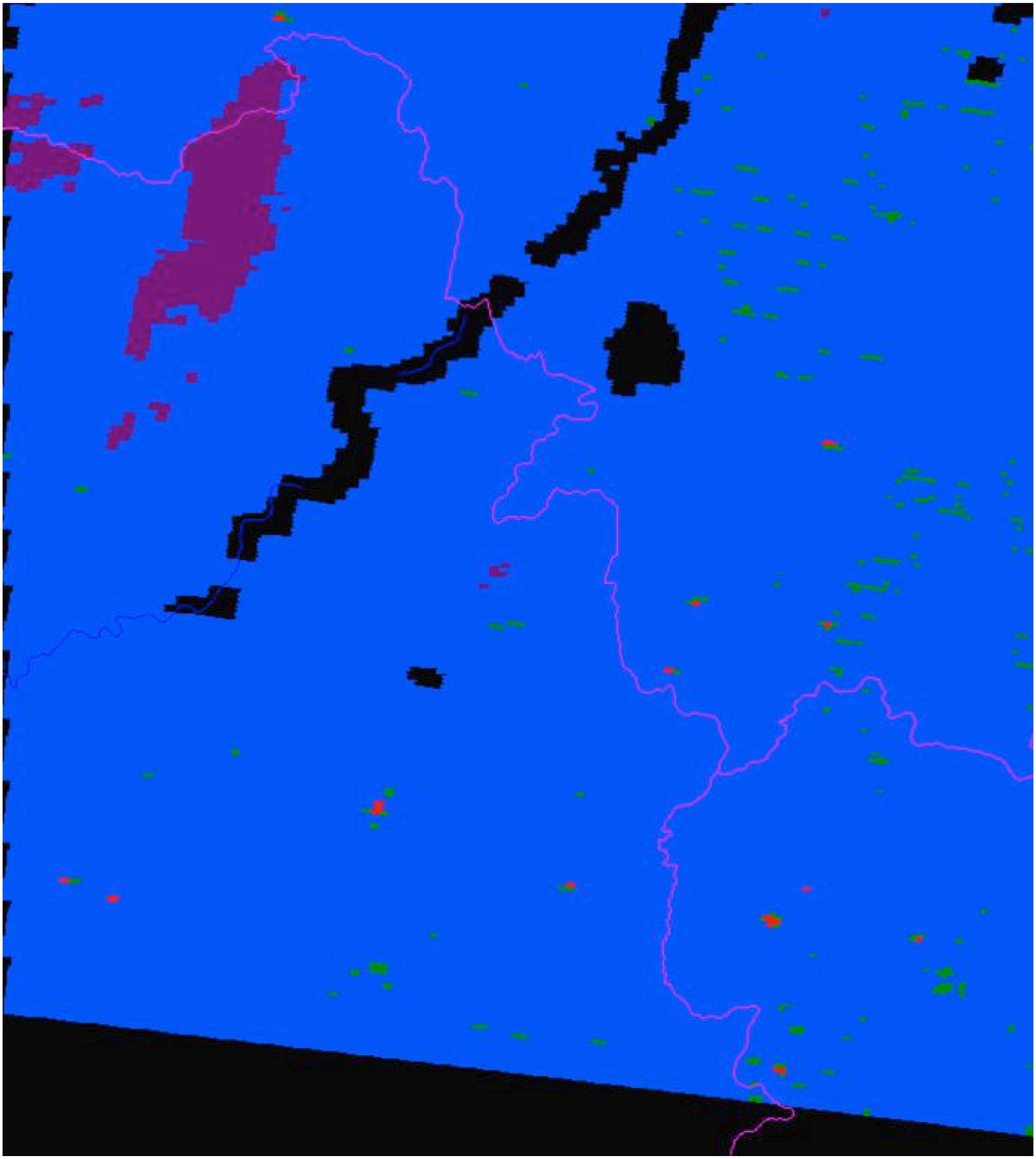

Figure 8e: Enlarged details over the red ellipse area, result of the contextual algorithm (MOD14) fires are red dots.

3. Aqua data evaluation

Aqua started acquiring data in late June 2002, the data were rapidely acquired by the Goddard DAAC, the level 1B were produced and shipped to the MODIS Adaptive Processing System (MODAPS), figure 9a shows some of the first 1B granules produced over Australia and stitched together over Australia using the HDFLook_MODIS software (http://eosdata.gsfc.nasa.gov/MODIS/HDFLook/). Figure 9b shows an enlargement of the previous image and some of the smoke plumes near the city of Darwin in the top left portion of the image. The at launch Aqua surface reflectance product (Figure 9c) is qualitatively good and we can see how the smoke plumes are removed through the atmospheric correction. Figure 9d shows the thermal anomaly for that granule, some red dots (fire) are visible in the top left part of the image, more obvious in figure 9e where the area of interest have been enlarged. When compared to Terra thermal anomaly (figure 9f), the number of fires is greater in the afternoon (Aqua) than in the morning data (Terra) that is consistent with the statistic derived from TRMM-VIIRS data set. Finally, we show on figure 9g the surface reflectance product from Aqua using an updated version of the PGE (version 3.1.9) which was put in operation on July, 12, 2002 which introduces small changes to accommodate the fact that band 6 could not be used on Aqua. In comparison to the Terra product (Figure 9h), which has much more maturity, the Aqua product looks of comparable quality which is very encouraging at this early stage of product evaluation.

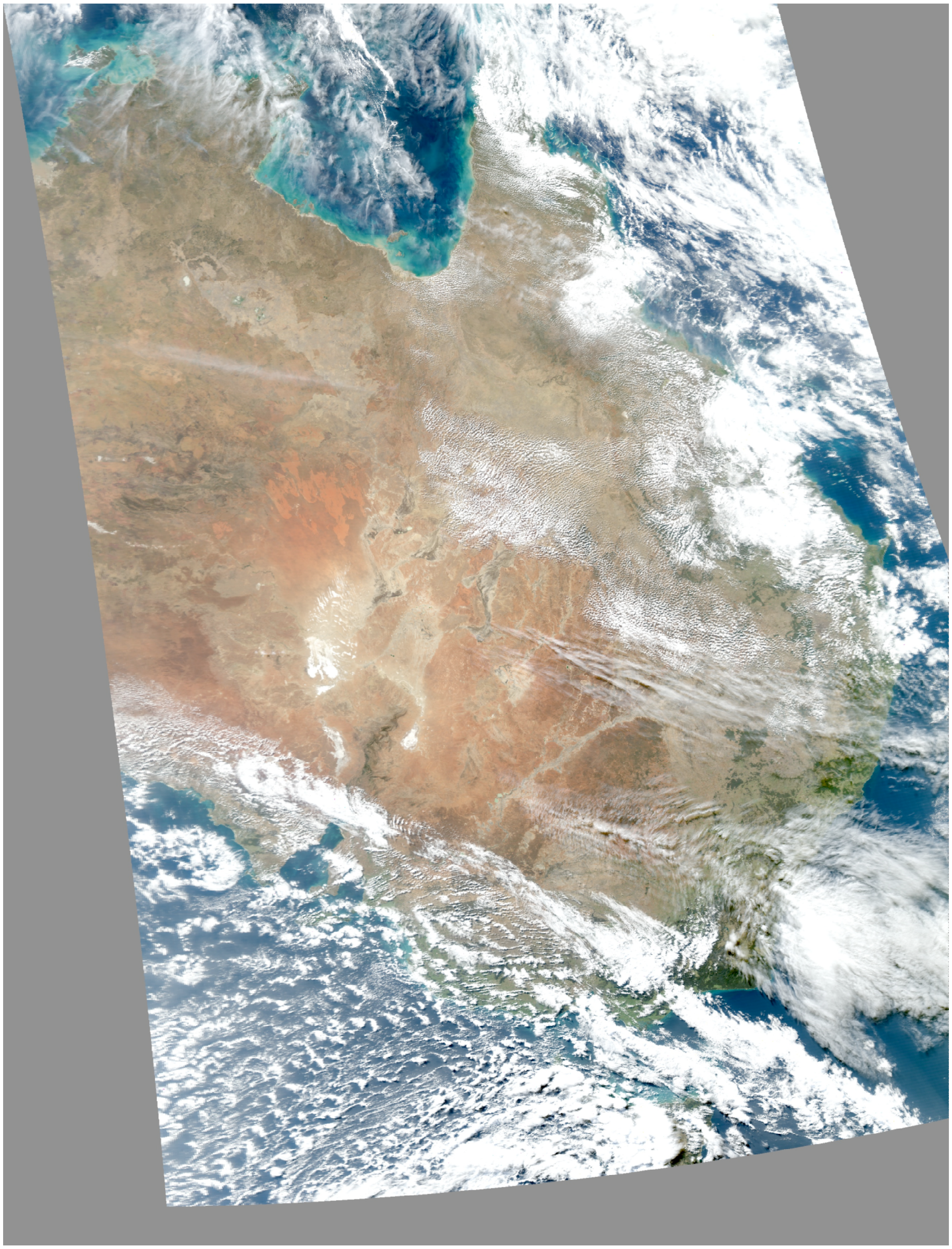

Figure 9a: MODIS Aqua first data (10min) over Australia (2002176 4:15 to 4:25 GMT) processed by the Goddard DAAC (image: El Saleous/HDFLookMODIS).

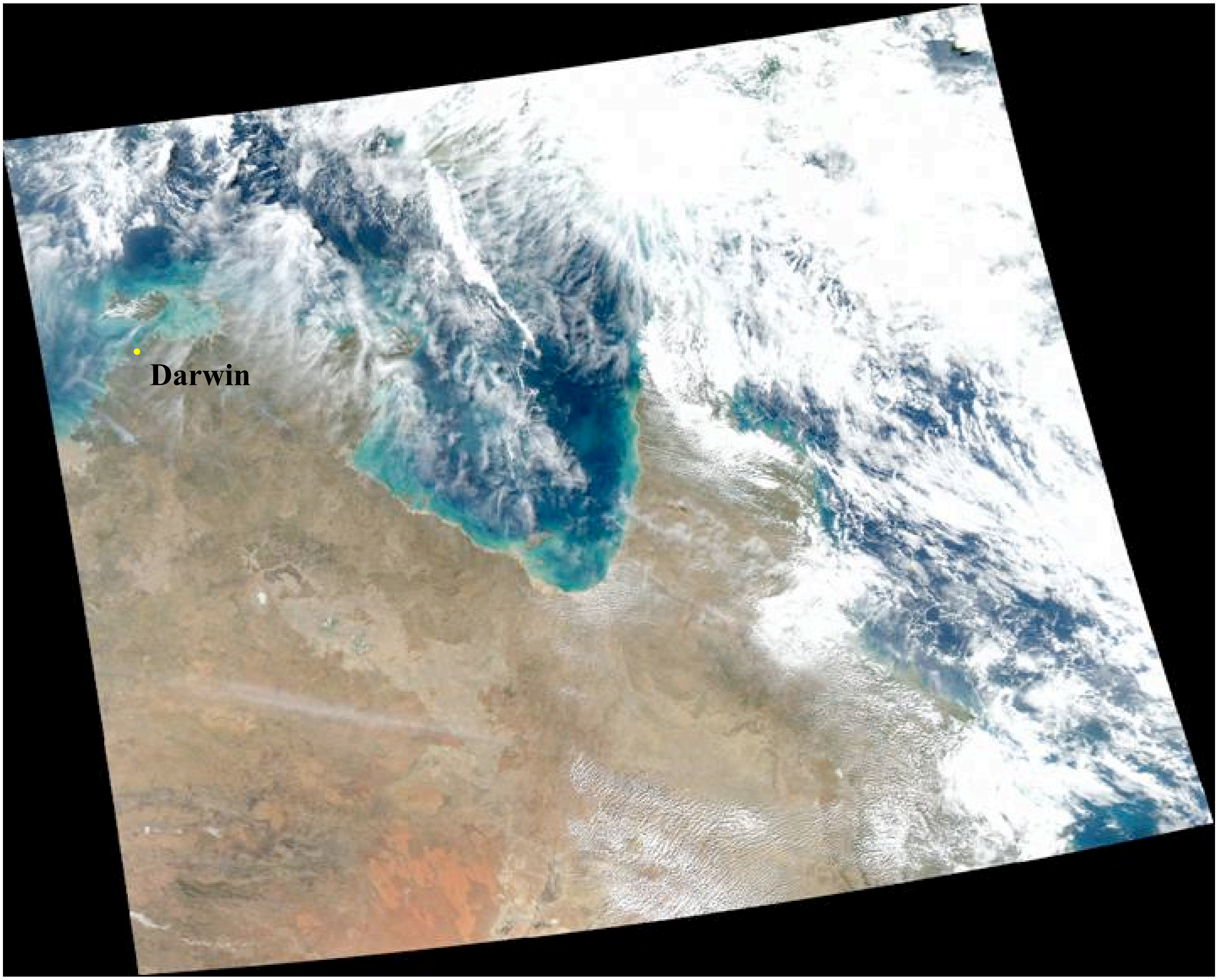

Figure 9b: Aqua true color RGB based on the L1B corrected reflectances over Australia (year 2002, Julian day 176, 4:15GMT). The red dot points at the city of Darwin in the vegetated part of Northern Autralia, a number of smoke plumes can be seen at the south of Darwin.

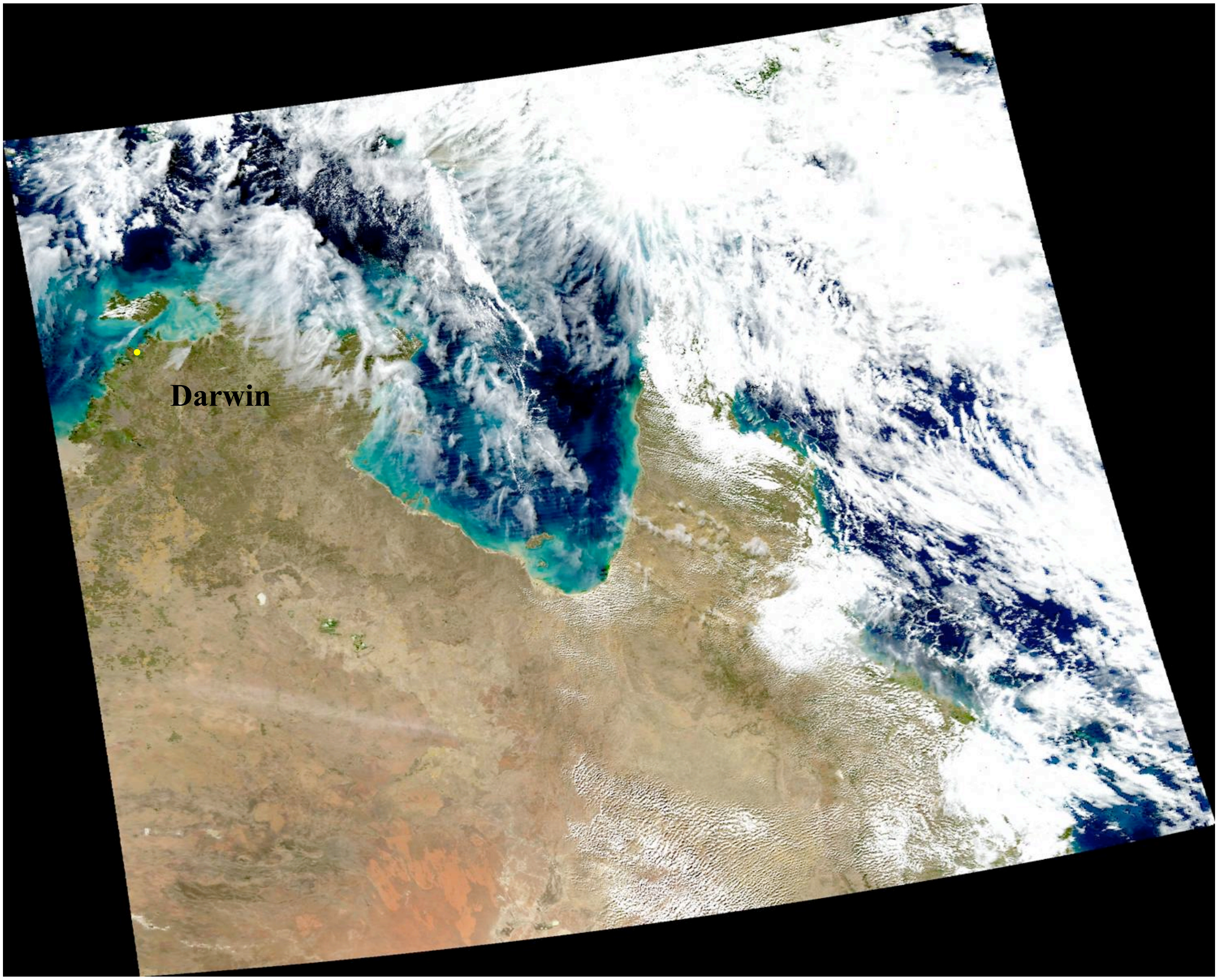

Figure 9c: Aqua true color RGB based on the MOD09 surface reflectance at launch PGE over Australia (year 2002, Julian day 176, 4:15GMT). Note how a lot of smoke plumes have been cleared out by the aerosol correction in the top left portion of the image.

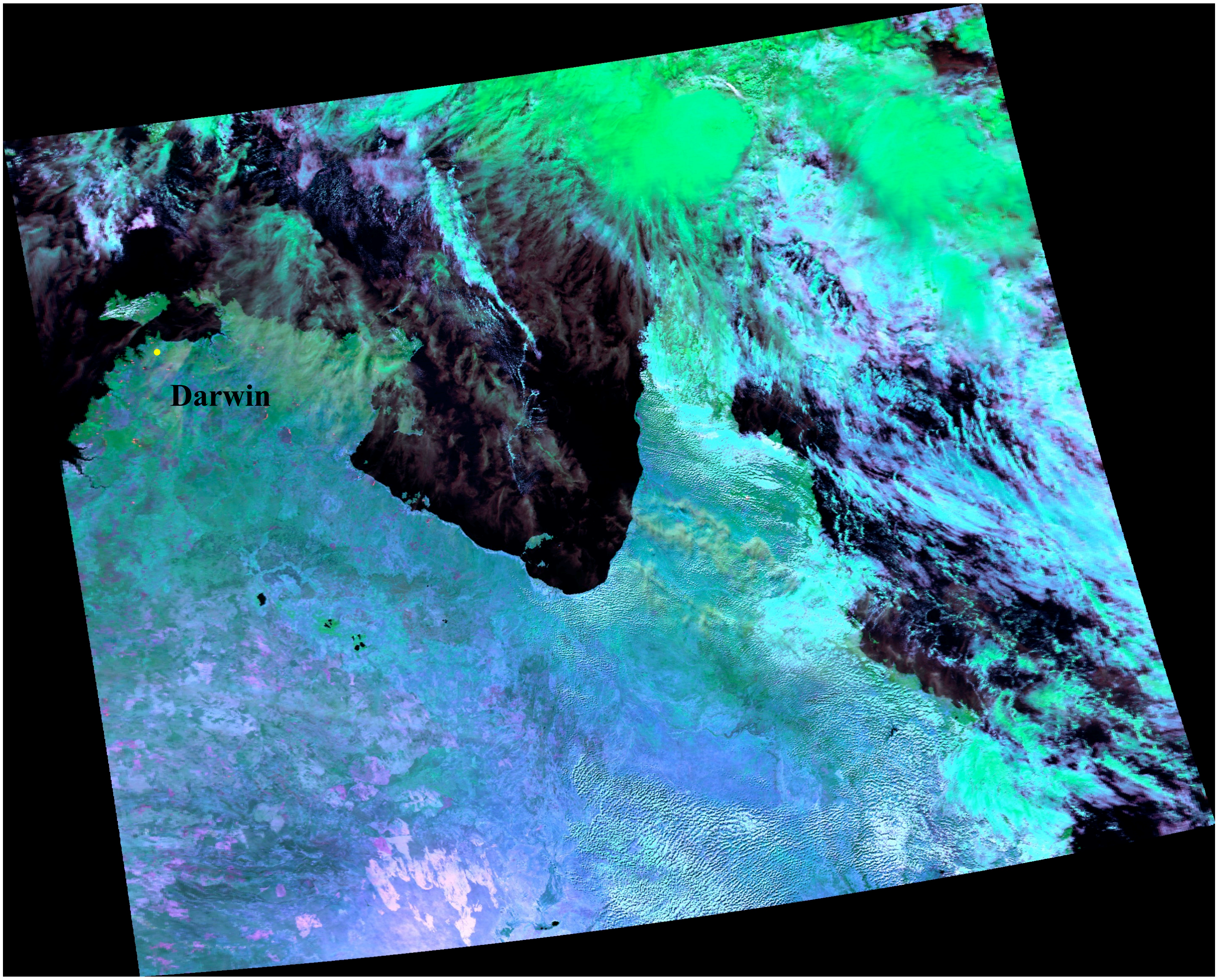

Figure 9d: Aqua thermal anomaly RGB over Australia (year 2002, Julian day 176, 4:15GMT), using RED: 3.75mic, G: 1.20mic, B: 2.13mic). Note that band 6 used in Terra thermal anomaly RGB has been replaced by band 5 since half of the detector of band 6 are not operable on the Aqua instrument.

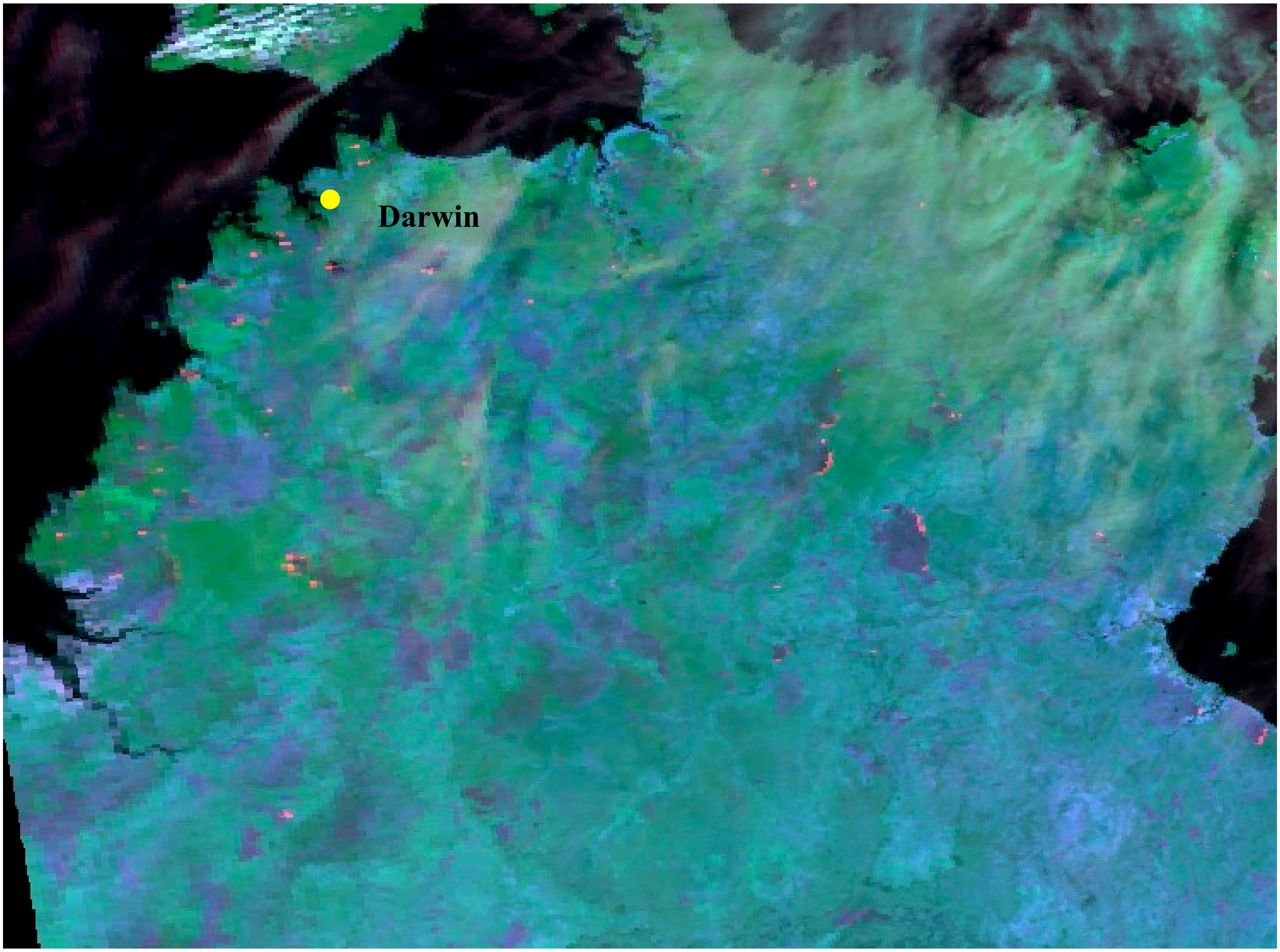

Figure 9e: Aqua thermal anomaly RGB over north of Australia using RED: 3.75mic, G: 1.20mic, B: 2.13mic). Note that band 6 used in Terra thermal anomaly RGB has been replaced by band 5 since half of the detectors of band 6 are not operable on the Aqua instrument. Fire activities (red dots) are clearly visible.

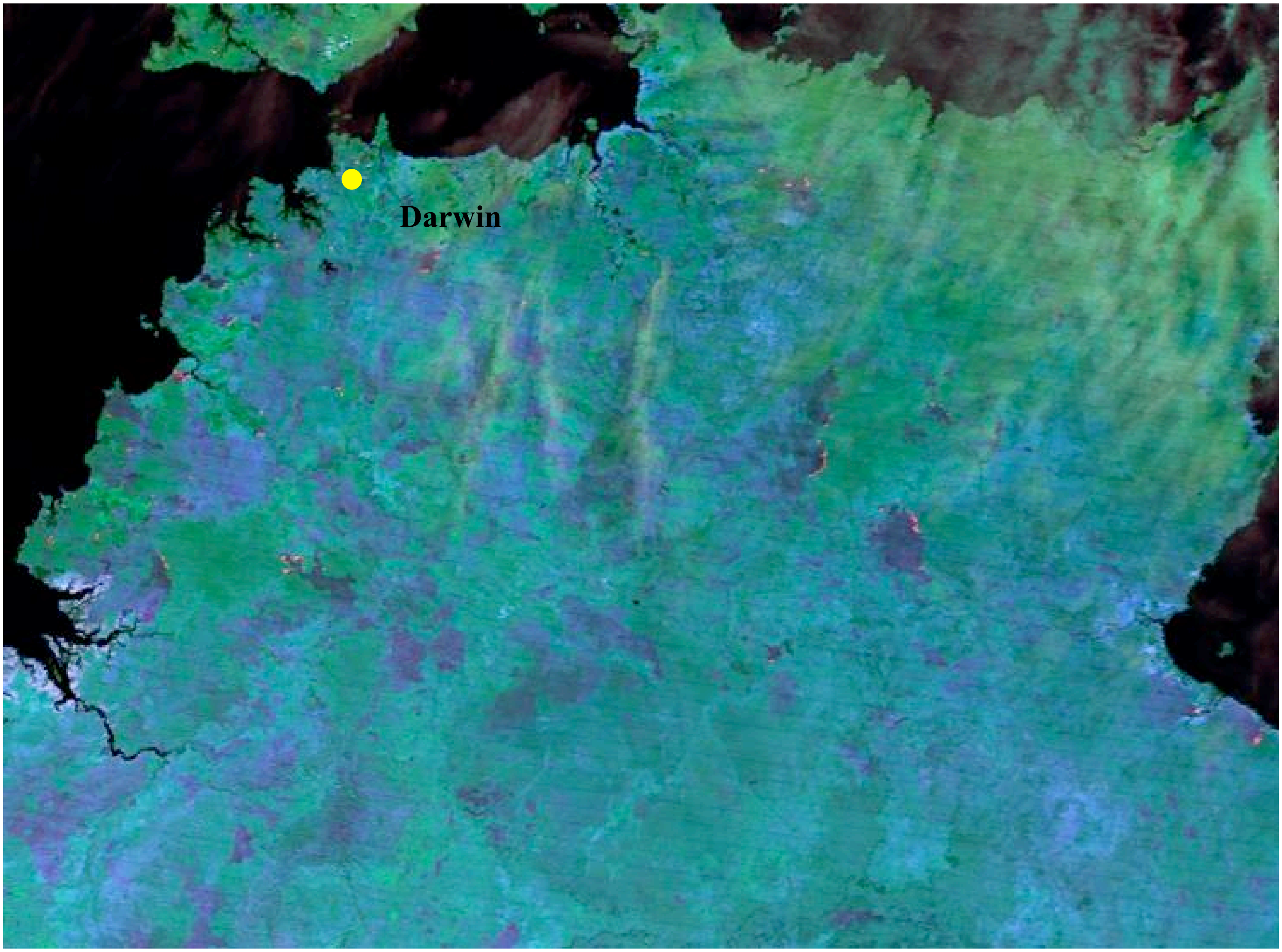

Figure 9f: Terra thermal anomaly RGB over north of Australia using RED: 3.75mic, G: 1.20mic, B: 2.13mic. Fire activities (red dots) are clearly visible but to a lesser extent to what can be seen on Aqua data (Figure 9e) which is consistent with statistics of fire occurrences collected from the TRMM-VIIRS data that show that the peak of the fire activity is in the afternoon.

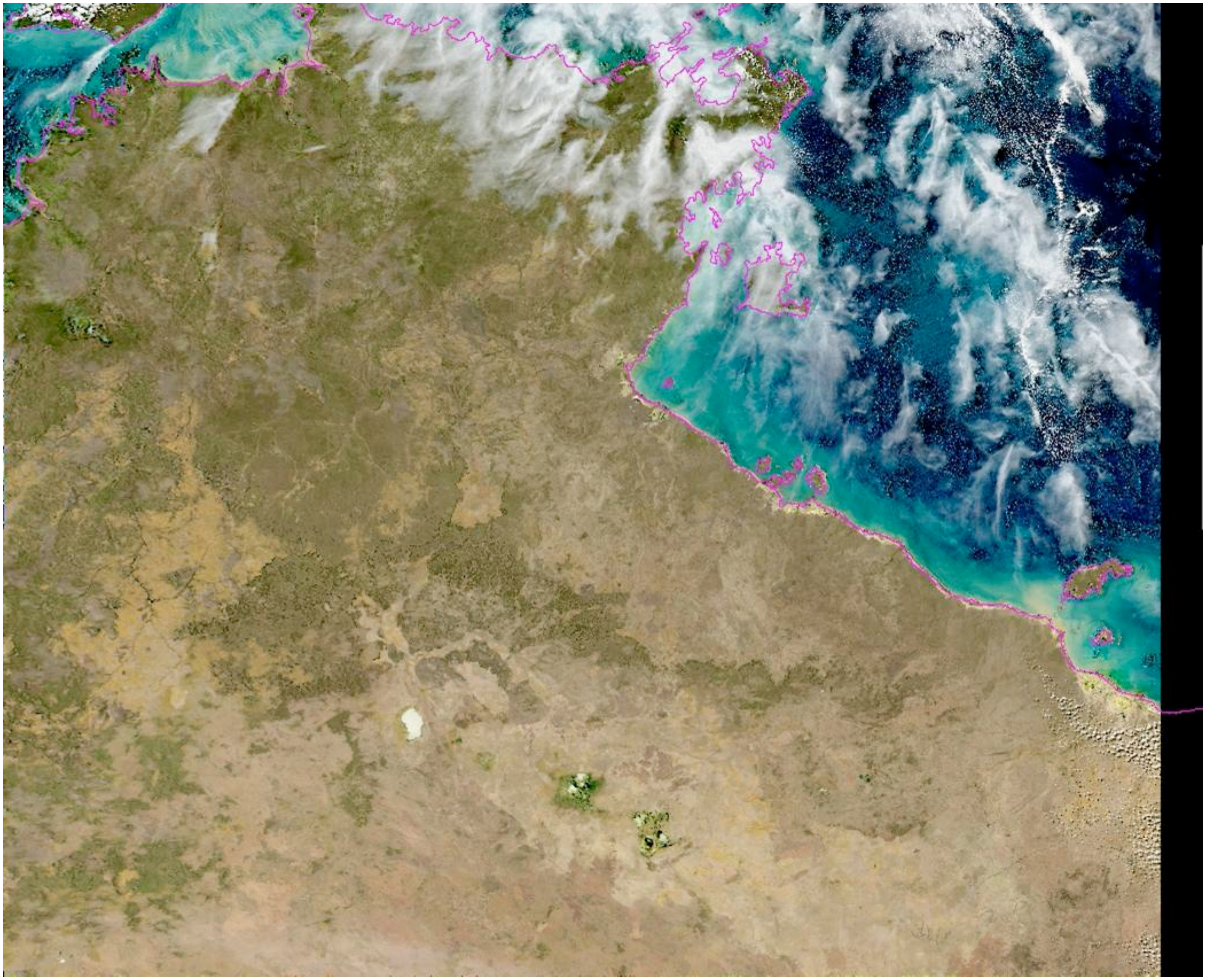

Figure 9g: True color RGB over north of Australia from Aqua MOD09 surface reflectance data (PGE version 3.1.9), the aerosol retrieval approach has been adapted to substitute band 6 with band 5 in the estimate of blue and red surface reflectance. This version of the surface reflectance appears very good qualitatively when compared to the Terra product (Figure 9h).

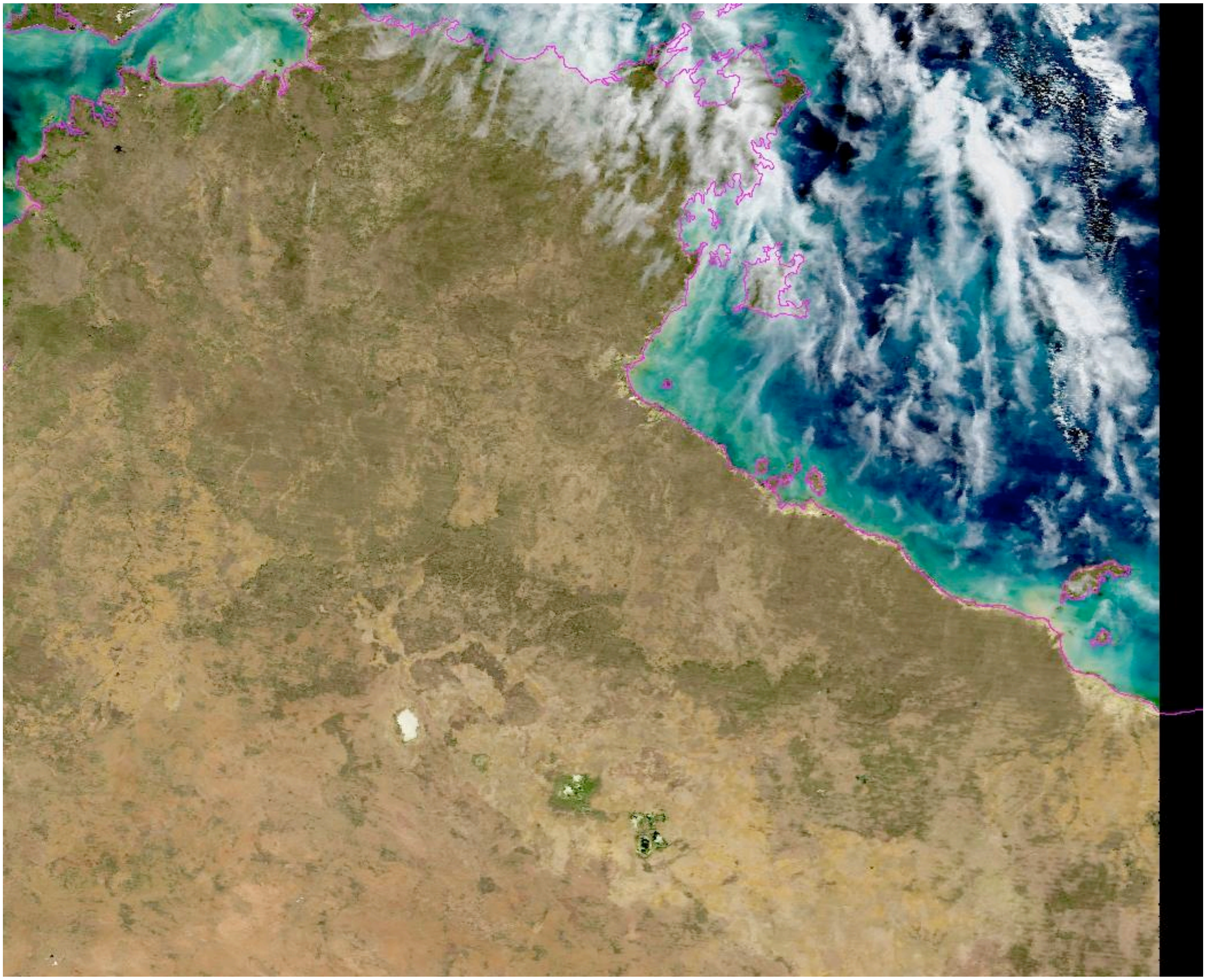

Figure 9h: True color RGB over north of Australia from Terra MOD09 surface reflectance data (PGE version 3.1.7).

4. 3.75mic reflectance and associated products

The evaluation of the post launch reflectance product at 3.75mic is continuing. The approach used for MODIS, which relies on temperature independent spectral indices (TISI) originally developed by Becker and Li (1990), has been reviewed and will soon be published in the peer-reviewed literature (Petitcolin and Vermote, 2002). Some additional efforts have been put into validating the associated products which represent intermediate step in reflectance inversion process: surface temperature and emissivity. Comparisons have been done with the official MODIS product (MOD11) but more specifically over test area where the ASTER team have been active. ASTER data are useful to scale up surface measurements at high spatial resolution to coarser MODIS resolution and therefore have attracted our interested. Figure 10a shows the land surface temperature derived from the TISI approach over the study area (La Jornada) located in New Mexico. Figure 10b and 10c shows comparison of the inverted surface temperature and emissivity in MODIS band 29 and 31 with the closest wavelength available on ASTER. It should be noted that the algorithm used for ASTER and MODIS are pretty close as far as atmospheric correction is concerned, they differ substantially for the estimate of emissivity, MODIS using the TISI approach and ASTER using a spectral library approach. The fact that their results are in good agreement is very comforting.

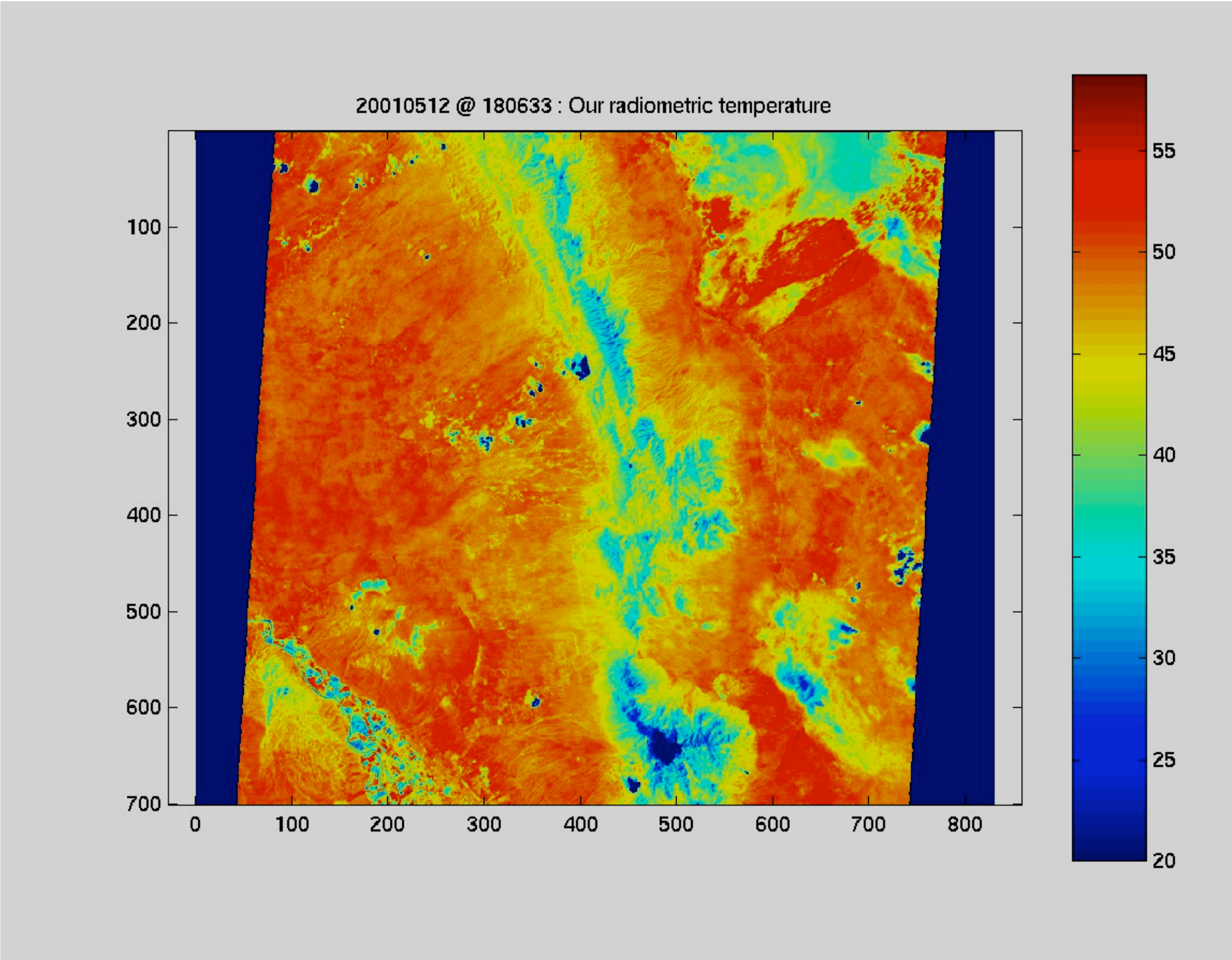

Figure 10a: Land surface temperature derived from the MODIS data using the approach described in Petitcolin and Vermote (2002) over the La Jornada site on May, 12, 2001.

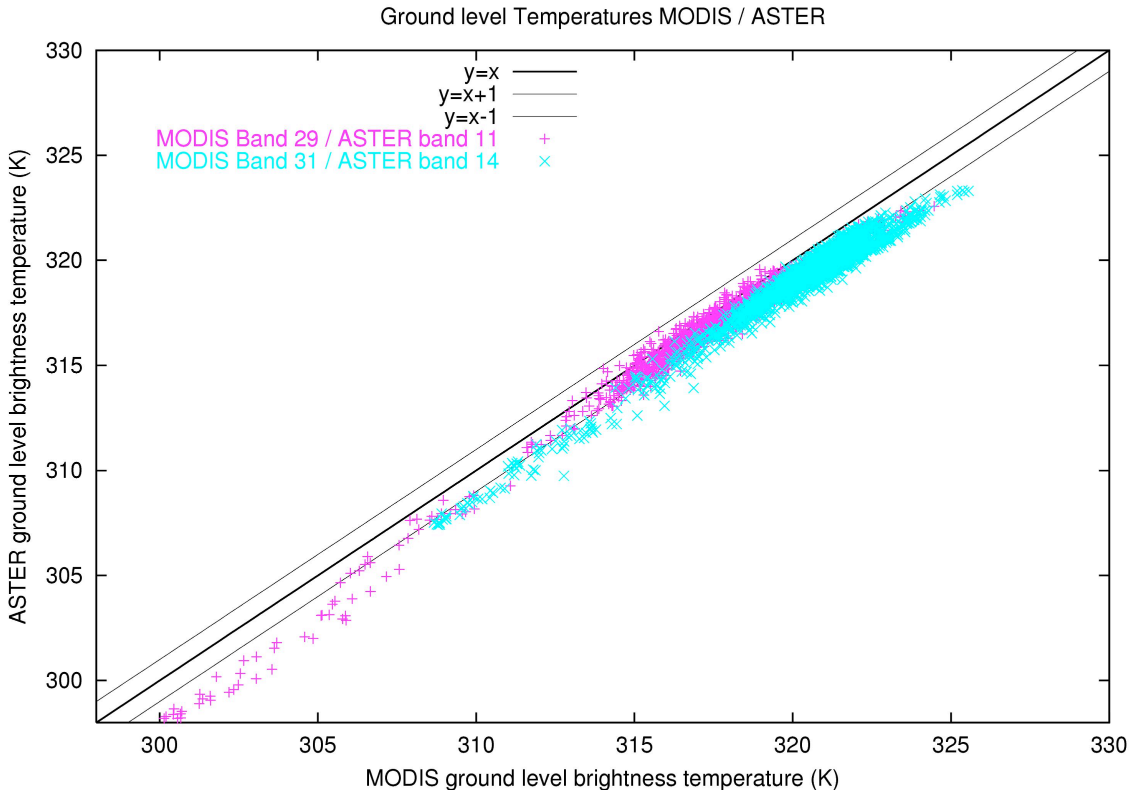

Figure 10b: Comparison of the MODIS derived surface temperature (TISI approach) with the land surface temperature derived from ASTER data using the USDA-ARS method.

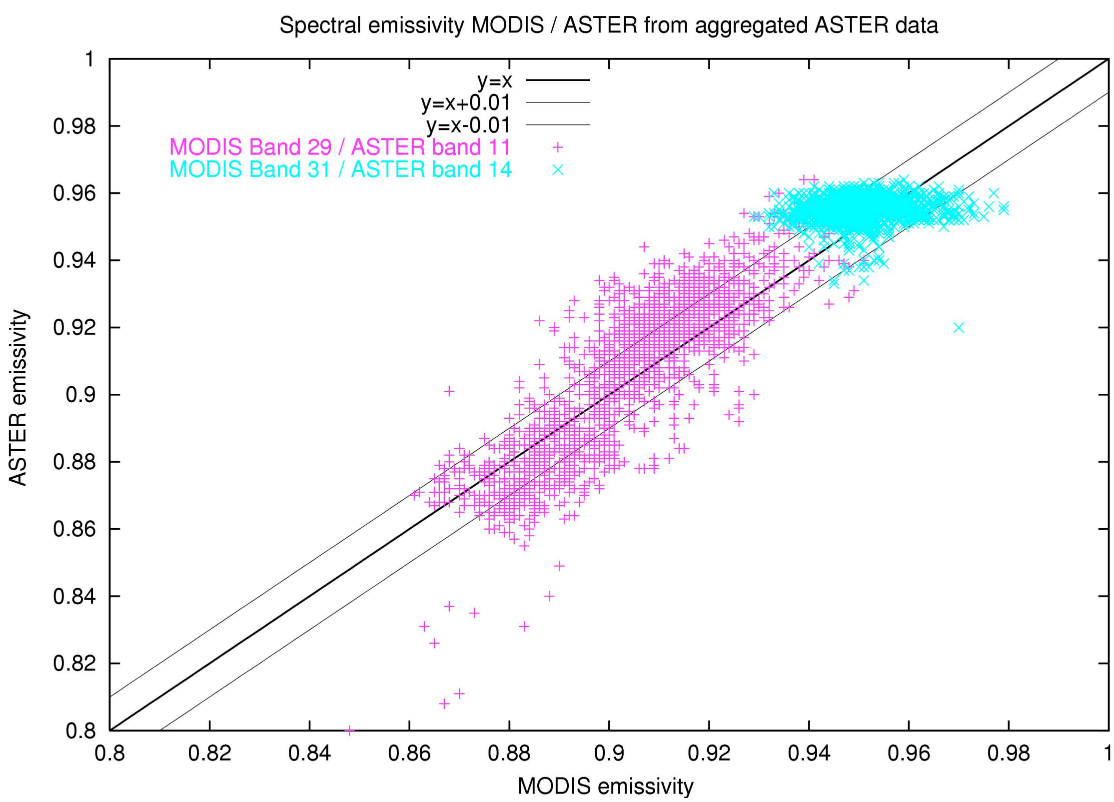

Figure 10c: Comparison of the MODIS derived emissivities (TISI approach) with the emissivities derived from ASTER data using the USDA-ARS method.

5. Development of continental data set from MOD09A1 (8 days composite surface reflectance).

We have started using the 8 days surface reflectance to put together a continental data set that could be presented as large size RGB poster for educational purposes. These activities also enable us to further increase the Quality Assurance of the surface reflectance product by carefully inspecting higher quality data selected by compositing several 8 days period together. Those activities also drove us to implement a simple correction for BRDF effect using the Ross Thick Li Sparse Model currently used for derivation of albedo or nadir adjusted data (MOD43 product suite). The first data set of the series has been produced over South Africa, and has been using MOD09A1 data spanning from February, 2, 2002 to May, 8, 2002. The postscript file which corresponds to a 135cmx135cm poster is available for download from the SCF web site,

Figure 11: South Africa true RGB image produced from MOD09A1 data from the February, 2, 2002 to May, 8, 2002 period. The poster (150dpi) produced using those data is 135cm by 135cm using 500m data.

6. Evidence of directional hot spot in surface reflectance

The use routine aerosol correction on relatively high spatial resolution data (250m) enables us to easily locate and observe features theoretically predicted by canopy radiative transfer models such as the directional Hot Spot, which is the relatively sharp increase of the surface reflectance in the antisolar direction. This feature could be simply explained by the fact that this particular geometry minimize the amount mutual shadowing between the reflective materials and therefore increase the total reflected energy in that particular direction. MODIS surface data shows clearly that effect as it can be seen on figure 12a and 12b. That interesting feature has been published as a cover letter to the International Journal of Remote Sensing (Vermote and Roy, 2002).

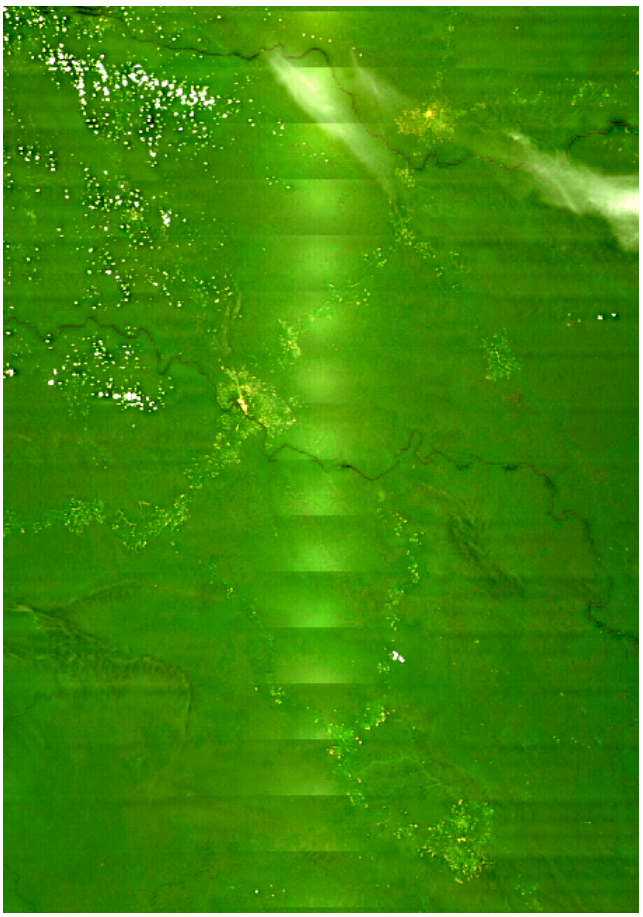

Figure 12a: Hot-spot effect observed by MODIS Ovr dense forest in the Democratic Republic of Congo as displayed by the RGB true color image of surface reflectance. The bright circular regions falling along a vertical axis through the centre of the image show hot-spot effects in successive MODIS scans.

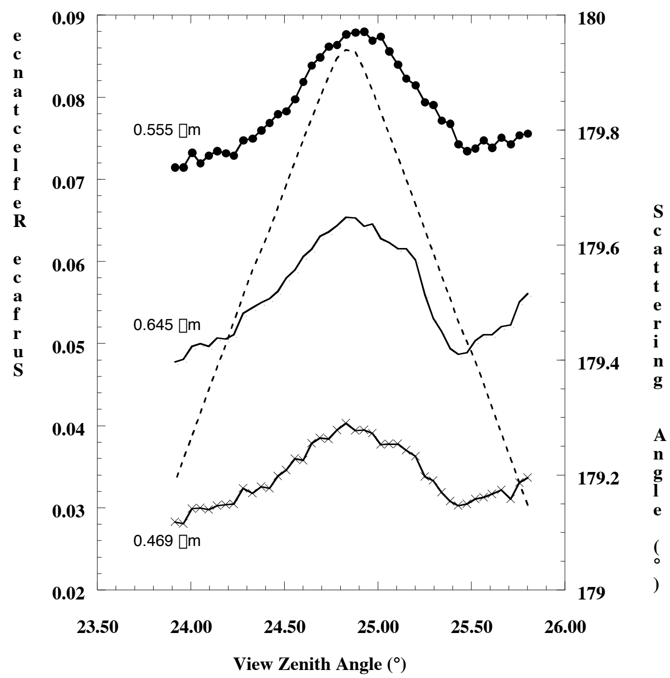

Figure 12b: Reflectances for a 20km transect along a scan line thorugh one of the central hot-spots shown in figure 12a. The maximum scattering anle (dahed line) coincide with the hot-spot as predicted by the theory.

7.0 MODIS Adaptive Processing System (MODAPS) / PI Processing

The Land Surface Reflectance SCF remains actively involved in the PI-led processing activity ranging from making sure that PI's needs are accurately perceived by the MODAPS development team and by management, as well as participating in the development of the processing system and various phases of testing.

The SCF participated in the weekly PI-Processing meetings where Eric Vermote represented the land group.

The SCF also participated in all of the weekly MODAPS meetings/telecons, where problems were discussed to identify solutions and where progress in the new development was tracked.

B. **MEETINGS ATTENDED**

- Monitoring Surface Reflectance using MODIS, MIT/Goddard Short Course Remote Sensing of the Earth's Environment from Terra Goddard Space Flight Center (January,02)
- European Geophysical Society XXVII General assembly (April 2002)
- SIVAM (System for the Vigilance of the Amazon) Technology Transfer Seminar IX, Manaus, Brazil, (June 2002.)
- IGARSS 2002, Toronto, Canada (June,2002)
- MODIS Science Team Meeting, (July 2002)
- Weekly PI Processing Status Meetings, NASA/GSFC.
- Weekly Technical Team Meetings, NASA/GSFC.
- Bi-Weekly SDDT (Science Data Discipline Team) Meetings.
- Weekly MsWG (MCST Science Working Group) Meeting

C. **PUBLICATIONS**

Ouaidrari, H., Goward, S.N. , Czajkowski, K.P. , Sobrino, J.A., Vermote, E.F., 2002, Land Surface Temperature Estimation from AVHRR Thermal Infrared Measurements: An Assessment for the AVHRR Land Pathfinder II Data Set, Remote Sensing of Environment, (In press)

Ouaidrari H., El Saleous N., Vermote E. F., Townshend J. R., Goward S. N., "AVHRR Land Pathfinder II (ALP II) data set: Evaluation and inter-comparison with other data sets", *International Journal of Remote Sensing* (In press)

Vermote E.F., “Adjacency effect on Remotely Sensed Data: Theory and Correction”, contribution to the *Encyclopedia of optical engineering,* Driggers R.G. and E. Lichtenstein (Eds.), publisher Marcel Dekker, Inc., (In press)

Privette J.L. and Vermote E.F**.**, “The Impact of Atmospheric Effects on Directional Reflectance Measurements”, Chapter 6 of Reflection properties of Vegetation and Soil - with a BRDF Data base, Maria von Schönermark, Bernhard Geiger, and Hans-Peter Röser (Eds)), 2002, publisher Wissenschaft & Technik Verlag (In press).

Ouaidrari, H., Goward, S.N. , Czajkowski, K.P. , Sobrino, J.A., Vermote, E.F., 2002, Land Surface Temperature Estimation from AVHRR Thermal Infrared Measurements: An Assessment for the AVHRR Land Pathfinder II Data Set, Remote Sensing of Environment, (In press)

Vermote E.F., El Saleous N, Justice C, 2002, Atmospheric correction of the MODIS data in the visible to middle infrared: First results, *(in press)*.

Vermote, E. F. and Roy, D.P.,2002, Land Surface Hot-Spot observed by MODIS over Central Africa, *International Journal of Remote Sensing*, Cover Letter, (11): 2141-2143.

Justice CO, Townshend JRG, Vermote EF, Masuoka E, Wolfe RE, Saleous N, Roy DP, Morisette JT,2002, An overview of MODIS Land data processing and product status, Remote Sensing Of Environment, (In press)

Petitcollin F. and Vermote E. F., 2002, Land Surface Reflectance, Emisivity and Temperature from MODIS Middle and Thermal Infrared data, *Remote Sensing Of Environment*, (In press)